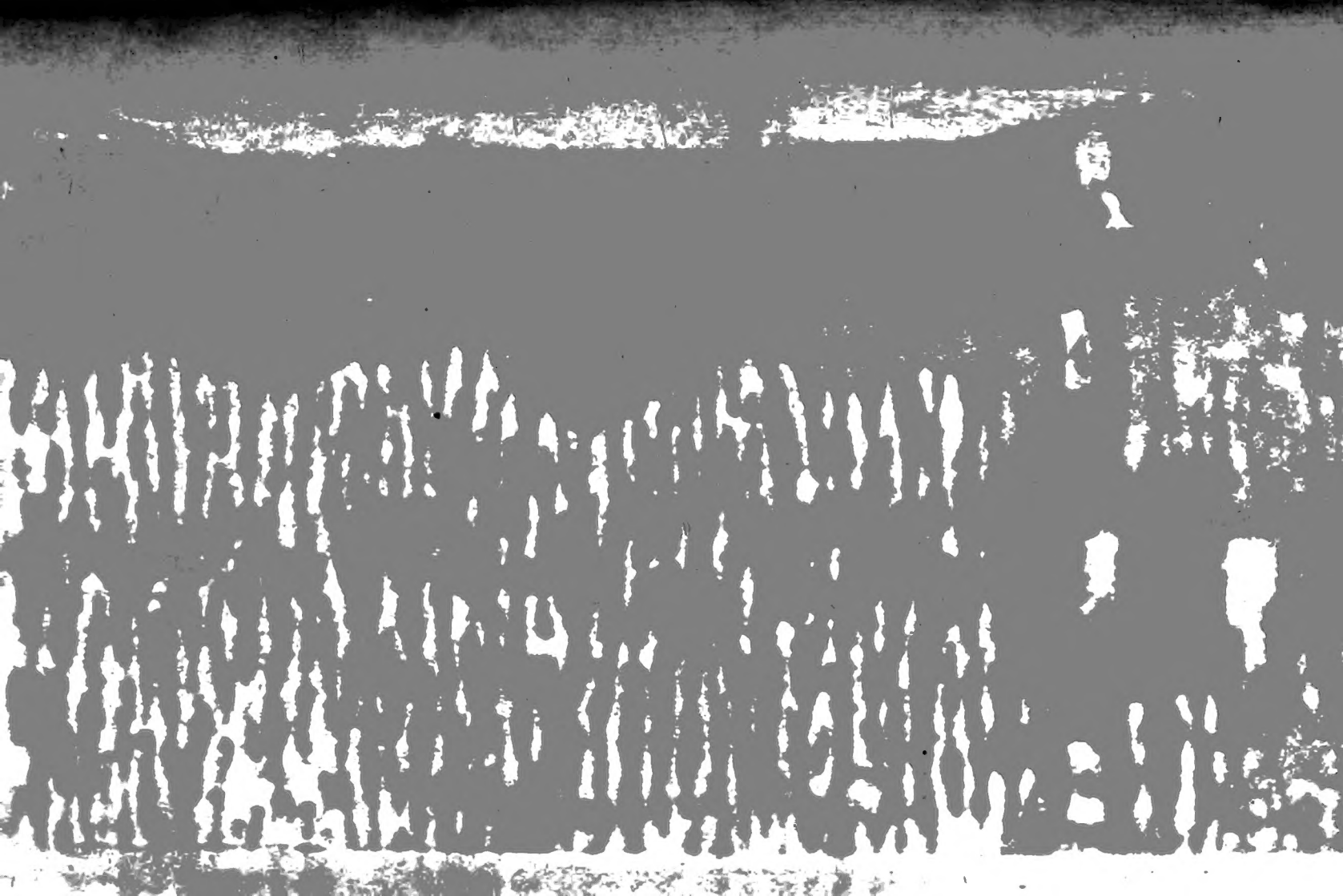

REPORT

OF THE

EIGHTY-SEVENTH MEETING OF THE

BRITISH ASSOCIATION

FOR THE ADVANCEMENT OF SCIENCE

BRITISH MUSEUM
NATURAL HISTORY

BOURNEMOUTH: 1919

SEPTEMBER 9—13

LONDON
JOHN MURRAY, ALBEMARLE STREET
1920

Office of the Association: Burlington House, London, W. 1.

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OFFICERS AND COUNCIL, 1919–20.

PATRON.

HIS MAJESTY THE KING.

PRESIDENT.

THE HON. SIR CHARLES A. PARSONS, K.C.B., M.A., LL.D., D.Sc., F.R.S.

VICE-PRESIDENTS.

Their Worships the MAYORS OF BOURNEMOUTH, CHRISTCHURCH, and POOLE.
The Right Rev. the LORD BISHOP OF WINCHESTER.
The Right Rev. the LORD BISHOP OF SALISBURY.
The Most Noble the MARQUESS OF SALISBURY, K.G., G.C.V.O.
The Right Hon. the EARL OF SHAFTESBURY, K.C.V.O., K.P.
The Right Hon. the EARL OF MALMESBURY, M.A., D.L., J.P.
The Right Hon. the EARL OF NORTHBROOK.
The Right Hon. the EARL OF SELBORNE, K.G., G.C.M.G., P.C., D.C.L., LL.D., J.P.
The Right Hon. LORD WIMBORNE, P.C.
Field-Marshal LORD GRENFELL, P.C., G.C.B., G.C.M.G.
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ALEX. HILL, Esq., O.B.E., M.A., M.D.

PRESIDENT ELECT.

Professor W. A. HERDMAN, C.B.E., D.Sc., LL.D., F.R.S.

VICE-PRESIDENTS ELECT.

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The Most Noble the MARQUIS OF BUTE.
The Right Hon. the EARL OF PLYMOUTH, P.C. (Lord-Lieutenant of the County of Glamorgan).
Major-Gen. the Right Hon. LORD TREOWEN, C.B., C.M.G. (Lord-Lieutenant of the County of Monmouth).
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The Right Hon. LORD PONTYPRIDD, D.L.
The Right Hon. LORD TREDEGAR, D.L.
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Principal A. H. TROW, D.Sc. (Principal of University College of S. Wales and Monmouthshire; President, Cardiff Naturalists' Society).
J. DYER LEWIS (President, South Wales Institute of Engineers).
R. O. SANDERSON (President, Cardiff Chamber of Commerce).

GENERAL TREASURER.

Professor JOHN PERRY, D.Sc., LL.D., F.R.S., Burlington House, London, W. 1.

GENERAL SECRETARIES.

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ASSISTANT SECRETARY.

O. J. R. HOWARTH, O.B.E., M.A., Burlington House, London, W. 1.

CHIEF CLERK AND ASSISTANT TREASURER.

H. C. STEWARDSON, Burlington House, London, W. 1.

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BONE, Professor W. A., F.R.S.
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DENDY, Professor A., F.R.S.
DIXEY, Dr. F. A., F.R.S.
DYSON, Sir F. W., F.R.S.
FOWLER, Professor A., F.R.S.
GREGORY, Sir R. A.
GRIFFITHS, Dr. E. H., F.R.S.
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KELTIE, Sir J. Scott.
KIRKALDY, Professor A. W.
MORRIS, Sir D., K.C.M.G.
PERKIN, Professor W. H., F.R.S.
RIVERS, Dr. W. H. R., F.R.S.
RUSSELL, Dr. E. J., O.B.E., F.R.S.
SAUNDERS, Miss E. R.
SCOTT, Professor W. R.
STARLING, Professor E. H., F.R.S.
STRAHAN, Sir Aubrey, F.R.S.
WHITAKER, W., F.R.S.
WOODWARD, Dr. A. SMITH, F.R.S.

OFFICERS AND COUNCIL

LOCAL TREASURERS FOR THE MEETING AT CARDIFF.

ARCHIBALD BROWN. | Sir THOMAS E. WATSON.

LOCAL SECRETARIES FOR THE MEETING AT CARDIFF.

CECIL G. BROWN, Town Clerk of Cardiff.
W. EVANS HOYLE, M.A., D.Sc.

EX-OFFICIO MEMBERS OF THE COUNCIL.

The Trustees, past Presidents of the Association, the President and Vice-Presidents for the year, the President and Vice-Presidents Elect, past and present General Treasurers and General Secretaries, past Assistant General Secretaries, and the Local Treasurers and Local Secretaries for the ensuing Annual Meeting.

TRUSTEES (PERMANENT).

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Sir ARTHUR EVANS, M.A., LL.D., F.R.S., F.S.A.

PAST PRESIDENTS OF THE ASSOCIATION.

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Sir James Dewar, F.R.S.
Sir Norman Lockyer, K.C.B., F.R.S.
Arthur J. Balfour, O.M., F.R.S.
Sir E. Ray Lankester, K.C.B., F.R.S.
Sir Francis Darwin, F.R.S.
Sir J. J. Thomson, O.M., Pres.R.S.
Professor T. G. Bonney, F.R.S.
Sir E. Sharpey Schäfer, F.R.S.
Sir Oliver Lodge, F.R.S.
Professor W. Bateson, F.R.S.
Sir Arthur Schuster, F.R.S.
Sir Arthur Evans, F.R.S.

PAST GENERAL OFFICERS OF THE ASSOCIATION.

Professor T. G. Bonney, F.R.S.
Sir E. Sharpey Schäfer, F.R.S.
Dr. D. H. Scott, F.R.S.
Dr. J. G. Garson.
Major P. A. MacMahon, F.R.S.
Professor W. A. Herdman, C.B.E., F.R.S.

HON. AUDITORS.

Sir EDWARD BRABROOK, C.B. | Professor A. BOWLEY.

RULES OF
THE BRITISH ASSOCIATION.

[*Adopted by the General Committee at Leicester*, 1907, *with subsequent amendments.*]

Chapter I.

Objects and Constitution.

Objects.

1. The objects of the British Association for the Advancement of Science are: To give a stronger impulse and a more systematic direction to scientific inquiry; to promote the intercourse of those who cultivate Science in different parts of the British Empire with one another and with foreign philosophers; to obtain more general attention for the objects of Science and the removal of any disadvantages of a public kind which impede its progress.

The Association contemplates no invasion of the ground occupied by other Institutions.

Constitution.

2. The Association shall consist of Members and Honorary Corresponding Members.

The governing body of the Association shall be a General Committee, constituted as hereinafter set forth; and its affairs shall be directed by a Council and conducted by General Officers appointed by that Committee.

Annual Meetings.

3. The Association shall meet annually, for one week or longer, and at such other times as the General Committee may appoint. The place of each Annual Meeting shall be determined by the General Committee not less than two years in advance; and the arrangements for these meetings shall be entrusted to the Officers of the Association.

Chapter II.

The General Committee.

Constitution.

1. The General Committee shall be constituted of the following persons:—

(i) *Permanent Members*—

(*a*) Past and present Members of the Council, and past and present Presidents of the Sections.

(*b*) Members who, by the publication of works or papers, have furthered the advancement of knowledge in any of those departments which are assigned to the Sections of the Association.

(ii) *Temporary Members*—

(*a*) Vice-Presidents and Secretaries of the Sections.
(*b*) Honorary Corresponding Members, foreign representatives, and other persons specially invited or nominated by the Council or General Officers.
(*c*) Delegates nominated by the Affiliated Societies.
(*d*) Delegates—not exceeding altogether three in number—from Scientific Institutions established at the place of meeting.

Admission.

2. The decision of the Council on the qualifications and claims of any Member of the Association to be placed on the General Committee shall be final.

(i) Claims for admission as a Permanent Member must be lodged with the Assistant Secretary at least one month before the Annual Meeting.
(ii) Claims for admission as a Temporary Member may be sent to the Assistant Secretary at any time before or during the Annual Meeting.

Meetings.

3. The General Committee shall meet twice at least during every Annual Meeting. In the interval between two Annual Meetings, it shall be competent for the Council at any time to summon a meeting of the General Committee.

Functions.

4. The General Committee shall—

(i) Receive and consider the Report of the Council.
(ii) Elect a Committee of Recommendations.
(iii) Receive and consider the Report of the Committee of Recommendations.
(iv) Determine the place of the Annual Meeting not less than two years in advance.
(v) Determine the date of the next Annual Meeting.
(vi) Elect the President and Vice-Presidents, Local Treasurer, and Local Secretaries for the next Annual Meeting.
(vii) Elect Ordinary Members of Council.
(viii) Appoint General Officers.
(ix) Appoint Auditors.
(x) Elect the Officers of the Conference of Delegates.
(xi) Receive any notice of motion for the next Annual Meeting.

Chapter III.

Committee of Recommendations.

Constitution.

1. * The *ex officio* Members of the Committee of Recommendations are the President and Vice-Presidents of the Association, the President of each Section at the Annual Meeting, the President of the Conference of Delegates, the General Secretaries, the General Treasurer, the Trustees, and the Presidents of the Association in former years.

An Ordinary Member of the Committee for each Section shall be nominated by the Committee of that Section.

If the President of a Section be unable to attend a meeting of the Committee of Recommendations, the Sectional Committee may appoint a Vice-President, or some other member of the Committee, to attend in his place, due notice of such appointment being sent to the Assistant Secretary.

Functions.

2. Every recommendation made under Chapter IV. and every resolution on a scientific subject, which may be submitted to the Association by any Sectional Committee, or by the Conference of Delegates, or otherwise than by the Council of the Association, shall be submitted to the Committee of Recommendations. If the Committee of Recommendations approve such recommendation, they shall transmit it to the General Committee; and no recommendation shall be considered by the General Committee that is not so transmitted.

Every recommendation adopted by the General Committee shall, if it involve action on the part of the Association, be transmitted to the Council; and the Council shall take such action as may be needful to give effect to it, and shall report to the General Committee not later than the next Annual Meeting.

Every proposal for establishing a new Section or Sub-Section, for altering the title of a Section, or for any other change in the constitutional forms or fundamental rules of the Association, shall be referred to the Committee of Recommendations for their consideration and report.

Procedure.

3. The Committee of Recommendations shall assemble, for the despatch of business, on the Monday of the Annual Meeting, and, if necessary, on the following day. Their Report must be submitted to the General Committee on the last day of the Annual Meeting.

* Amended by the General Committee at Winnipeg, 1909, and Manchester, 1915.

Chapter IV.

Research Committees.

Procedure.

1. Every proposal for special research, or for a grant of money in aid of special research, which is made in any Section, shall be considered by the Committee of that Section; and, if such proposal be approved, it shall be referred to the Committee of Recommendations.

In consequence of any such proposal, a Sectional Committee may recommend the appointment of a Research Committee to conduct research or administer a grant in aid of research, and in any case to report thereon to the Association; and the Committee of Recommendations may include such recommendation in their Report to the General Committee.

Such Research Committee shall be composed of Members of the Association, provided that it shall be competent for the General Committee to appoint, or for a Research Committee to co-opt, as an assessor or consultative member, any person, not being a Member of the Association, whose assistance may be regarded as of special importance to the research undertaken.*

Constitution.

2. Every appointment of a Research Committee shall be proposed at a meeting of the Sectional Committee and adopted at a subsequent meeting. The Sectional Committee shall settle the terms of reference and suitable Members to serve on it, which must be as small as is consistent with its efficient working; and shall nominate a Chairman and a Secretary. Such Research Committee, if appointed, shall have power to add to their numbers.

Proposals by Sectional Committees.

3. The Sectional Committee shall state in their recommendation whether a grant of money be desired for the purposes of any Research Committee, and shall estimate the amount required.

All proposals sanctioned by a Sectional Committee shall be forwarded by the Recorder to the Assistant Secretary not later than noon on the Monday of the Annual Meeting for presentation to the Committee of Recommendations.

Tenure.

4. Research Committees are appointed for one year only. If the work of a Research Committee cannot be completed in that year, application may be made through a Sectional Committee at the next Annual Meeting for reappointment, with or without a grant—or a further grant—of money.

Reports.

5. Every Research Committee shall present a Report, whether interim or final, at the Annual Meeting next after that at which it was appointed or reappointed, and may in the

* Amended by the General Committee at Newcastle-upon-Tyne, 1916.

meantime present a Report through a Sectional Organising Committee to the Council.* Interim Reports, whether intended for publication or not, must be submitted in writing. Each Sectional Committee shall ascertain whether a Report has been made by each Research Committee appointed on their recommendation, and shall report to the Committee of Recommendations on or before the Monday of the Annual Meeting.

GRANTS

(*a*) Drawn by Chairman.

6. In each Research Committee to which a grant of money has been made, the Chairman is the only person entitled to call on the General Treasurer for such portion of the sum granted as from time to time may be required.

(*b*) Expire on June 30.

Grants of money sanctioned at the Annual Meeting expire on June 30 following. The General Treasurer is not authorised, after that date, to allow any claims on account of such grants.

(*c*) Accounts, and balance in hand.

The Chairman of a Research Committee must, before the Annual Meeting next following the appointment of the Research Committee, forward to the General Treasurer a statement of the sums that have been received and expended, together with vouchers. The Chairman must then return the balance of the grant, if any, which remains unexpended ; provided that a Research Committee may, in the first year of its appointment only, apply for leave to retain an unexpended balance when or before its Report is presented, due reason being given for such application.†

(*d*) Additional Grant.

When application is made for a Committee to be reappointed, and to retain the balance of a former grant, and also to receive a further grant, the amount of such further grant is to be estimated as being sufficient, together with the balance proposed to be retained, to make up the amount desired.

(*e*) *Caveat.*

In making grants of money to Research Committees, the Association does not contemplate the payment of personal expenses to the Members.

A Research Committee, whether or not in receipt of a grant, shall not raise money, in the name or under the auspices of the Association, without special permission from the General Committee.

Disposal of specimens, apparatus, &c.

7. Members and Committees entrusted with sums of money for collecting specimens of any description shall include in their Reports particulars thereof, and shall reserve the specimens thus obtained for disposal, as the Council may direct.

Committees are required to furnish a list of any apparatus which may have been purchased out of a grant made

* Amended by the General Committee at Newcastle-upon-Tyne, 1916.
† Amended by the General Committee at Dundee, 1912.

by the Association, and to state whether the apparatus is likely to be useful for continuing the research in question or for other specific purposes.

All instruments, drawings, papers, and other property of the Association, when not in actual use by a Committee, shall be deposited at the Office of the Association.

Chapter V.

The Council.

Constitution.

1. The Council shall consist of *ex officio* Members and of Ordinary Members elected annually by the General Committee.

(i) The *ex officio* Members are—the Trustees, past Presidents of the Association, the President and Vice-Presidents for the year, the President and Vice-Presidents Elect, past and present General Treasurers and General Secretaries, past Assistant General Secretaries, and the Local Treasurers and Local Secretaries for the ensuing Annual Meeting.

(ii) The Ordinary Members shall not exceed twenty-five in number. Of these, not more than twenty shall have served on the Council as Ordinary Members in the previous year.

Functions.

2. The Council shall have authority to act, in the name and on behalf of the Association, in all matters which do not conflict with the functions of the General Committee.

In the interval between two Annual Meetings, the Council shall manage the affairs of the Association and may fill up vacancies among the General and other Officers, until the next Annual Meeting.

The Council shall hold such meetings as they may think fit, and shall in any case meet on the first day of the Annual Meeting, in order to complete and adopt the Annual Report, and to consider other matters to be brought before the General Committee.

The Council shall nominate for election by the General Committee, at each Annual Meeting, a President and General Officers of the Association.

Suggestions for the Presidency shall be considered by the Council at the Meeting in February, and the names selected shall be issued with the summonses to the Council Meeting in March, when the nomination shall be made from the names on the list.

The Council shall have power to appoint and dismiss such paid officers as may be necessary to carry on the work of the Association, on such terms as they may from time to time determine. Elections.

3. Election to the Council shall take place at the same time as that of the Officers of the Association.

(i) At each Annual Election, the following Ordinary Members of the Council shall be ineligible for re-election in the ensuing year :

(*a*) Three of the Members who have served for the longest consecutive period, and

(*b*) Two of the Members who, being resident in or near London, have attended the least number of meetings during the past year.

Nevertheless, it shall be competent for the Council, by an unanimous vote, to reverse the proportion in the order of retirement above set forth.

(ii) The Council shall submit to the General Committee, in their Annual Report, the names of twenty-three Members of the Association whom they recommend for election as Members of Council.

(iii) Two Members shall be elected by the General Committee, without nomination by the Council ; and this election shall be at the same meeting as that at which the election of the other Members of the Council takes place.

Any member of the General Committee may propose another member thereof for election as one of these two Members of Council, and, if only two are so proposed, they shall be declared elected ; but, if more than two are so proposed, the election shall be by show of hands, unless five Members at least require it to be by ballot.

Chapter VI.

The President, General Officers, and Staff.

1. The President assumes office on the first day of the Annual Meeting, when he delivers a Presidential Address. He resigns office at the next Annual Meeting, when he inducts his successor into the Chair. The President.

The President shall preside at all meetings of the Association or of its Council and Committees which he attends in his capacity as President. In his absence, he shall be represented by a Vice-President or past President of the Association.

2. The General Officers of the Association are the General Treasurer and the General Secretaries. General Officers.

It shall be competent for the General Officers to act, in the name of the Association, in any matter of urgency which cannot be brought under the consideration of the Council; and they shall report such action to the Council at the next meeting.

The General Treasurer.

3. The General Treasurer shall be responsible to the General Committee and the Council for the financial affairs of the Association.

The General Secretaries.

4. The General Secretaries shall control the general organisation and administration, and shall be responsible to the General Committee and the Council for conducting the correspondence and for the general routine of the work of the Association, excepting that which relates to Finance.

The Assistant Secretary.

5. The Assistant Secretary shall hold office during the pleasure of the Council. He shall act under the direction of the General Secretaries, and in their absence shall represent them. He shall also act on the directions which may be given him by the General Treasurer in that part of his duties which relates to the finances of the Association.

The Assistant Secretary shall be charged, subject as aforesaid: (i) with the general organising and editorial work, and with the administrative business of the Association; (ii) with the control and direction of the Office and of all persons therein employed; and (iii) with the execution of Standing Orders or of the directions given him by the General Officers and Council. He shall act as Secretary, and take Minutes, at the meetings of the Council, and at all meetings of Committees of the Council, of the Committee of Recommendations, and of the General Committee.

Assistant Treasurer.

6. The General Treasurer may depute one of the Staff, as Assistant Treasurer, to carry on, under his direction, the routine work of the duties of his office.

The Assistant Treasurer shall be charged with the issue of Membership Tickets, the payment of Grants, and such other work as may be delegated to him.

Chapter VII.

Finance.

Financial Statements.

1. The General Treasurer, or Assistant Treasurer, shall receive and acknowledge all sums of money paid to the Association. He shall submit, at each meeting of the Council, an interim statement of his Account; and, after June 30 in each year, he shall prepare and submit to the General Committee a balance-sheet of the Funds of the Association.

Audit. 2. The Accounts of the Association shall be audited, annually, by Auditors appointed by the General Committee.

Expenditure. 3. The General Treasurer shall make all ordinary payments authorised by the General Committee or by the Council.

Investments. 4. The General Treasurer is empowered to draw on the account of the Association, and to invest on its behalf, part or all of the balance standing at any time to the credit of the Association in the books of the Bank of England, either in Exchequer Bills or in any other temporary investment, and to change, sell, or otherwise deal with such temporary investment as may seem to him desirable.

Cheques. 5. In the event of the General Treasurer being unable, from illness or any other cause, to exercise the functions of his office, the President of the Association for the time being and one of the General Secretaries shall be jointly empowered to sign cheques on behalf of the Association.

Chapter VIII.

The Annual Meetings.

Local Officers and Committees. 1. Local Committees shall be formed to assist the General Officers in making arrangements for the Annual Meeting, and shall have power to add to their number.

2. The General Committee shall appoint, on the recommendation of the Local Reception or Executive Committee for the ensuing Annual Meeting, a Local Treasurer or Treasurers and two or more Local Secretaries, who shall rank as officers of the Association, and shall consult with the General Officers and the Assistant Secretary as to the local arrangements necessary for the conduct of the meeting. The Local Treasurers shall be empowered to enrol Members, and to receive subscriptions.

Functions. 3. The Local Committees and Sub-Committees shall undertake the local organisation, and shall have power to act in the name of the Association in all matters pertaining to the local arrangements for the Annual Meeting other than the work of the Sections.

Chapter IX.

The Work of the Sections.

The Sections. 1. The scientific work of the Association shall be transacted under such Sections as shall be constituted from time to time by the General Committee.

It shall be competent for any Section, if authorised by the Council for the time being, to form a Sub-Section for the purpose of dealing separately with any group of communications addressed to that Section.

Sectional Officers.

2. There shall be in each Section a President, two or more Vice-Presidents, and two or more Secretaries. They shall be appointed by the Council, for each Annual Meeting in advance, and shall act as the Officers of the Section from the date of their appointment until the appointment of their successors in office for the ensuing Annual Meeting.

Of the Secretaries, one shall act as Recorder of the Section, and one shall be resident in the locality where the Annual Meeting is held.

Rooms.

3. The Section Rooms and the approaches thereto shall not be used for any notices, exhibitions, or other purposes than those of the Association.

SECTIONAL COMMITTEES.

4. The work of each Section shall be conducted by a Sectional Committee, which shall consist of the following :—

Constitution.

(i) The Officers of the Section during their term of office.

(ii) All past Presidents of that Section.

(iii) Such other Members of the Association, present at any Annual Meeting, as the Sectional Committee, thus constituted, may co-opt for the period of the meeting :

Provided always that—

Privilege of Old Members.

(*a*) Any Member of the Association who has served on the Committee of any Section in any previous year, and who has intimated his intention of being present at the Annual Meeting, is eligible as a member of that Committee at their first meeting.

Daily Co-optation.

(*b*) A Sectional Committee may co-opt members, as above set forth, at any time during the Annual Meeting, and shall publish daily a revised list of the members.

Additional Vice-Presidents.

(*c*) A Sectional Committee may, at any time during the Annual Meeting, appoint not more than three persons present at the meeting to be Vice-Presidents of the Section, in addition to those previously appointed by the Council.

EXECUTIVE FUNCTIONS

5. The chief executive officers of a Section shall be the President and the Recorder. They shall have power to act on behalf of the Section in any matter of urgency which cannot be brought before the consideration of the Sectional Committee ; and they shall report such action to the Sectional Committee at its next meeting.

Of President

The President (or, in his absence, one of the Vice-Presidents) shall preside at all meetings of the Sectional Committee or of the Section. His ruling shall be absolute on all points of order that may arise.

and of Recorder.

The Recorder shall be responsible for the punctual transmission to the Assistant Secretary of the daily programme of his Section, of the recommendations adopted by the Sectional Committee, of the printed returns, abstracts, reports, or papers appertaining to the proceedings of his Section at the Annual Meeting, and for the correspondence and minutes of the Sectional Committee.

Organising Committee.

6. The Sectional Committee shall nominate, before the close of the Annual Meeting, not more than six of its own members to be members of an Organising Committee, with the officers to be subsequently appointed by the Council, and past Presidents of the Section, from the close of the Annual Meeting until the conclusion of its meeting on the first day of the ensuing Annual Meeting.

Each Organising Committee shall hold such meetings as are deemed necessary by its President for the organisation of the ensuing Sectional proceedings, and may at any such meeting resolve to present a report to the Council upon any matter of interest to the Section,* and shall hold a meeting on the first Wednesday of the Annual Meeting : to nominate members of the Sectional Committee, to confirm the Provisional Programme of the Section, and to report to the Sectional Committee.

Sectional Committee.

Each Sectional Committee shall meet daily, unless otherwise determined, during the Annual Meeting : to co-opt members, to complete the arrangements for the next day, and to take into consideration any suggestion for the advancement of Science that may be offered by a member, or may arise out of the proceedings of the Section.

Papers and Reports.

No paper shall be read in any Section until it has been accepted by the Sectional Committee and entered as accepted on its Minutes.

Any report or paper read in any one Section may be read also in any other Section.

No paper or abstract of a paper shall be printed in the Annual Report of the Association unless the manuscript has been received by the Recorder of the Section before the close of the Annual Meeting.

Recommendations.

It shall be within the competence of the Sectional Committee to review the recommendations adopted at preceding

* Amended by the General Committee at Newcastle-upon-Tyne, 1916.

Annual Meetings, as published in the Annual Reports of the Association, and the communications made to the Section at its current meetings, for the purpose of selecting definite objects of research, in the promotion of which individual or concerted action may be usefully employed ; and, further, to take into consideration those branches or aspects of knowledge on the state and progress of which reports are required : to make recommendations and nominate individuals or Research Committees to whom the preparation of such reports, or the task of research, may be entrusted, discriminating as to whether, and in what respects, these objects may be usefully advanced by the appropriation of money from the funds of the Association, whether by reference to local authorities, public institutions, or Departments of His Majesty's Government. The appointment of such Research Committees shall be made in accordance with the provisions of Chapter IV.

No proposal arising out of the proceedings of any Section shall be referred to the Committee of Recommendations unless it shall have received the sanction of the Sectional Committee.

Publication.

7. Papers ordered to be printed *in extenso* shall not be included in the Annual Report, if published elsewhere prior to the issue of the Annual Report in volume form. Reports of Research Committees shall not be published elsewhere than in the Annual Report without the express sanction of the Council.

Copyright.

8. The copyright of papers ordered by the General Committee to be printed *in extenso* in the Annual Report shall be vested in the authors ; and the copyright of the Reports of Research Committees appointed by the General Committee shall be vested in the Association.

Chapter X.

*Admission of Members.**

Applications.

1. No technical qualification shall be required on the part of an applicant for admission as a Member of the British Association ; but the Council is empowered, in the event of special circumstances arising, to impose suitable conditions and restrictions in this respect.

Obligations.

Every person admitted as a Member shall conform to the Rules and Regulations of the Association, and for any infringement thereof shall be liable to exclusion by the Council, who have also authority, if they think it necessary, to withhold from any person the privilege of attending any

* Amended by the General Committee, 1908, 1918, 1919.

Annual Meeting or to cancel a ticket of admission already issued.

Expulsion.

If it appears to the Council that it is not desirable that a person shall continue to be a Member of the Association, the Council shall direct the General Secretaries to ascertain whether that person is willing to resign his membership.

If that person do not, within a time to be fixed by the Council, either resign or appeal in writing to the General Committee, the Council may declare such person to be no longer a Member. Upon the appeal, the General Committee may make the like declaration by a majority of two-thirds of those present and voting.

The Council shall also have power to refuse any application for membership.

It shall be competent for the General Officers to act, in the name of the Council, on any occasion of urgency which cannot be brought under the consideration of the Council; and they shall report such action to the Council at the next meeting.

Conditions and Privileges of Membership.

2. All Members, except as hereafter provided, are eligible to any office in the Association.

(i) Every *Life Member* hereafter admitted shall pay, on admission, the sum of Fifteen Pounds.

(ii) Every *Annual Member* shall pay, on admission, the sum of One Pound, and in any subsequent year the sum of One Pound.

(iii) University and other Students and Teachers, vouched for by the Local Executive Committee as resident or working in the locality where the Annual Meeting takes place, may obtain 'students' tickets' for the Meeting on payment of 10*s*. Holders of such tickets shall not be entitled to any privilege beyond attendance at the Annual Meeting.

(iv) Transferable tickets, admitting one person to any meeting or function during the Annual Meeting, shall be issued at the price of £1 5*s*. Holders of such tickets shall not be entitled to any privilege beyond such admission. No other tickets issued by the Association shall be transferable.

Corresponding Members.

3. Honorary Corresponding Members may be appointed by the General Committee, on the nomination of the Council. They shall be entitled to all the privileges of Membership.

Annual Subscriptions.

4. Subscriptions are payable at or before the Annual Meeting. Annual Members not attending the meeting may

make payment at any time before the close of the financial year on June 30 of the following year.

The Annual Report.

(i) Every Life Member, whether admitted before or after the adoption of these Rules, shall be entitled to receive *gratis*, on demand, the Annual Reports of the Association issued in and after the year of admission.

(ii) Annual Members attending an Annual Meeting shall be entitled to obtain the Report of that Meeting for an additional payment of 10*s.* made before or during the Annual Meeting, or of 12*s.* 6*d.* made after the Annual Meeting within a period not extending beyond the close of the financial year (June 30).

Provided that Annual Members who have paid the annual subscription of £1 without intermission from a date anterior to September 14, 1919, and continue to do so, shall be entitled to receive the Annual Report, on demand, without further payment.

(iii) Annual Members who pay the annual subscription of £1, but do not attend the Annual Meeting, shall be entitled to receive the Annual Report, on demand, without further payment.

(iv) Holders of Students' or transferable tickets shall not be entitled to receive the Annual Report on the terms above stated.

(v) Subject to any statutory rights, or other considerations in the discretion of the Council, libraries and institutions shall be entitled to purchase the Annual Volume at a subscription rate of 12*s.* 6*d.* per annum.

(vi) The publication price of the Annual Report shall be £1 5*s.*

(vii) Volumes not claimed within two years of the date of publication can only be issued by direction of the Council.

Chapter XI.

Corresponding Societies: Conference of Delegates.

Affiliated Societies.

Corresponding Societies are constituted as follows:

1. (i) Any Society which undertakes local scientific investigation and publishes the results may become a Society *affiliated* to the British Association.

Each Affiliated Society may appoint a Delegate, who must be or become a Member of the Association and must attend the meetings of the Conference of Delegates. He shall be *ex officio* a Member of the General Committee.

(ii) Any Society formed for the purpose of encouraging the study of Science, which has existed for three years and numbers not fewer than fifty members, may become a Society *associated* with the British Association. ASSOCIATED SOCIETIES.

Each Associated Society shall have the right to appoint a Delegate to attend the Annual Conference. Such Delegates must be or become Members of the British Association, and shall have all the rights of Delegates appointed by the Affiliated Societies, except that of membership of the General Committee.

2. Application may be made by any Society to be placed on the list of Corresponding Societies. Such application must be addressed to the Assistant Secretary on or before the 1st of June preceding the Annual Meeting at which it is intended it should be considered, and must, in the case of Societies desiring to be affiliated, be accompanied by specimens of the publications of the results of local scientific investigations recently undertaken by the Society. Applications.

3. A Corresponding Societies Committee shall be annually nominated by the Council and appointed by the General Committee, for the purpose of keeping themselves generally informed of the work of the Corresponding Societies and of superintending the preparation of a list of the papers published by the Affiliated Societies. This Committee shall make an Annual Report to the Council, and shall suggest such additions or changes in the list of Corresponding Societies as they may consider desirable. CORRESPONDING SOCIETIES COMMITTEE.

(i) Each Corresponding Society shall forward every year to the Assistant Secretary of the Association, on or before June 1,* such particulars in regard to the Society as may be required for the information of the Corresponding Societies Committee. Procedure.

(ii) There shall be inserted in the Annual Report of the Association a list of the papers published by the Corresponding Societies during the preceding twelve months which contain the results of local scientific work conducted by them—those papers only being included which refer to subjects coming under the cognisance of one or other of the several Sections of the Association.

4. The Delegates of Corresponding Societies shall constitute a Conference, of which the President,* Vice-President,* CONFERENCE OF DELEGATES.

* Amended by the General Committee at Manchester, 1915.

and Secretary or Secretaries shall be nominated annually by the Council and appointed by the General Committee. The members of the Corresponding Societies Committee shall be *ex officio* members of the Conference.

Procedure and Functions.

(i) The Conference of Delegates shall be summoned by the Secretaries to hold one or more meetings during each Annual Meeting of the Association, and shall be empowered to invite any Member to take part in the discussions.

(ii) The Conference of Delegates shall be empowered to submit Resolutions to the Committee of Recommendations for their consideration, and for report to the General Committee.

(iii) The Sectional Committees of the Association shall be requested to transmit to the Secretaries of the Conference of Delegates copies of any recommendations to be made to the General Committee bearing on matters in which the co-operation of Corresponding Societies is desirable. It shall be competent for the Secretaries of the Conference of Delegates to invite the authors of such recommendations to attend the meetings of the Conference in order to give verbal explanations of their objects and of the precise way in which they desire these to be carried into effect.

(iv) It shall be the duty of the Delegates to make themselves familiar with the purport of the several recommendations brought before the Conference, in order that they may be able to bring such recommendations adequately before their respective Societies.

(v) The Conference may also discuss propositions regarding the promotion of more systematic observation and plans of operation, and of greater uniformity in the method of publishing results.

Chapter XII.

Amendments and New Rules.

Alterations.

Any alterations in the Rules, and any amendments or new Rules that may be proposed by the Council or individual Members, shall be notified to the General Committee on the first day of the Annual Meeting, and referred forthwith to the Committee of Recommendations; and, on the report of that Committee, shall be submitted for approval at the last meeting of the General Committee.

TRUSTEES, GENERAL OFFICERS, &c., 1831–1919.

TRUSTEES.

1832–70 (Sir) R. I. Murchison (Bart.), F.R.S.
1832–62 John Taylor, Esq., F.R.S.
1832–39 C. Babbage, Esq., F.R.S.
1839–44 F. Baily, Esq., F.R.S.
1844–58 Rev. G. Peacock, F.R.S.
1858–82 General E. Sabine, F.R.S.
1862–81 Sir P. Egerton, Bart., F.R.S.
1872–1913 Sir J. Lubbock, Bart. (afterwards Lord Avebury), F.R.S.
1881–83 W. Spottiswoode, Esq., Pres.R.S.
1883–1919 Lord Rayleigh, F.R.S.
1883–98 Sir Lyon (afterwards Lord) Playfair, F.R.S.
1898–1915 Prof. (Sir) A. W. Rücker, F.R.S.
1913– Major P. A. MacMahon, F.R.S.
1915–19 Dr. G. Carey Foster, F.R.S.
1919– Sir A. Evans, F.R.S.

GENERAL TREASURERS.

1831 Jonathan Gray, Esq.
1832–62 John Taylor, Esq., F.R.S.
1862–74 W. Spottiswoode, Esq., F.R.S.
1874–91 Prof. A. W. Williamson, F.R.S.
1891–98 Prof. (Sir) A. W. Rücker, F.R.S.
1898–1904 Prof. G. C. Foster, F.R.S.
1904– Prof. John Perry, F.R.S.

GENERAL SECRETARIES.

1832–35 Rev. W. Vernon Harcourt, F.R.S.
1835–36 Rev. W. Vernon Harcourt, F.R.S., and F. Baily, Esq., F.R.S.
1836–37 Rev. W. Vernon Harcourt, F.R.S., and R. I. Murchison, Esq., F.R.S.
1837–39 R. I. Murchison, Esq., F.R.S., and Rev. G. Peacock, F.R.S.
1839–45 Sir R. I. Murchison, F.R.S., and Major E. Sabine, F.R.S.
1845–50 Lieut.-Colonel E. Sabine, F.R.S.
1850–52 General E. Sabine, F.R.S., and J. F. Royle, Esq., F.R.S.
1852–53 J. F. Royle, Esq., F.R.S.
1853–59 General E. Sabine, F.R.S.
1859–61 Prof. R. Walker, F.R.S.
1861–62 W. Hopkins, Esq., F.R.S.
1862–63 W. Hopkins, Esq., F.R.S., and Prof. J. Phillips, F.R.S.
1863–65 W. Hopkins, Esq., F.R.S., and F. Galton, Esq., F.R.S.
1865–66 F. Galton, Esq., F.R.S.
1866–68 F. Galton, Esq., F.R.S., and Dr. T. A. Hirst, F.R.S.
1868–71 Dr. T. A. Hirst, F.R.S., and Dr. T. Thomson, F.R.S.
1871–72 Dr. T. Thomson, F.R.S., and Capt. Douglas Galton, F.R.S.
1872–76 Capt. D. Galton, F.R.S., and Dr. Michael Foster, F.R.S.
1876–81 Capt. D. Galton, F.R.S., and Dr. P. L. Sclater, F.R.S.
1881–82 Capt. D. Galton, F.R.S., and Prof. F. M. Balfour, F.R.S.
1882–83 Capt. Douglas Galton, F.R.S.
1883–95 Sir Douglas Galton, F.R.S., and A. G. Vernon Harcourt, Esq., F.R.S.
1895–97 A. G. Vernon Harcourt, Esq., F.R.S., and Prof. E. A. Schäfer, F.R.S.
1897–1900 Prof. Schäfer, F.R.S., and Sir W. C. Roberts-Austen, F.R.S.
1900–02 Sir W. C. Roberts-Austen, F.R.S., and Dr. D. H. Scott, F.R.S.
1902–03 Dr. D. H. Scott, F.R.S., and Major P. A. MacMahon, F.R.S.
1903–13 Major P. A. MacMahon, F.R.S., and Prof. W. A. Herdman, F.R.S.
1913–19 Prof. W. A. Herdman, F.R.S., and Prof. H. H. Turner, F.R.S.
1919– Prof. H. H. Turner, F.R.S., and Prof. J. L. Myres.

ASSISTANT GENERAL SECRETARIES, &c.: 1831–1904.

1831 John Phillips, Esq., *Secretary.*
1832 Prof. J. D. Forbes, *Acting Secretary.*
1832–62 Prof. John Phillips, F.R.S.
1862–78 G. Griffith, Esq., M.A.
1881 G. Griffith, Esq., M.A., *Acting Secretary.*
1881–85 Prof. T. G. Bonney, F.R.S., *Secretary.*
1885–90 A. T. Atchison, Esq., M.A., *Secretary.*
1890 G. Griffith, Esq., M.A., *Acting Secretary.*
1890–1902 G. Griffith, Esq., M.A.
1902–04 J. G. Garson, Esq., M.D.

ASSISTANT SECRETARIES.

1878–80 J. E. H. Gordon, Esq., B.A.
1904–09 A. Silva White, Esq.
1909– O. J. R. Howarth, Esq., M.A.

Presidents and Secretaries of the Sections of the Association, 1901–1916.

(The List of Sectional Officers for 1919 will be found on p. xliii.)

Date and Place	Presidents	Secretaries (*Rec.* = Recorder)
SECTION A.[1]—MATHEMATICS AND PHYSICS.		
1901. Glasgow ...	Major P. A. MacMahon, F.R.S. —*Dep. of Astronomy*, Prof. H. H. Turner, F.R.S.	H. S. Carslaw, C. H. Lees (*Rec.*), W. Stewart, Prof. L. R. Wilberforce.
1902. Belfast.....	Prof. J. Purser, LL.D., M.R.I.A. —*Dep. of Astronomy*, Prof. A. Schuster, F.R.S.	H. S. Carslaw, A. R. Hinks, A. Larmor, C. H. Lees (*Rec.*), Prof. W. B. Morton, A. W. Porter.
1903. Southport	C. Vernon Boys, F.R.S.—*Dep. of Astronomy and Meteorology*, Dr. W. N. Shaw, F.R.S.	D. E. Benson, A. R. Hinks, R. W. H. T. Hudson, Dr. C. H. Lees (*Rec.*), J. Loton, A. W. Porter.
1904. Cambridge	Prof. H. Lamb, F.R.S.—*Sub-Section of Astronomy and Cosmical Physics*, Sir J. Eliot, K.C.I.E., F.R.S.	A. R. Hinks, R. W. H. T. Hudson, Dr. C. H. Lees (*Rec.*), Dr. W. J. S. Lockyer, A. W. Porter, W. C. D. Whetham.
1905. South Africa	Prof. A. R. Forsyth, M.A., F.R.S.	A. R. Hinks, S. S. Hough, R. T. A. Innes, J. H. Jeans, Dr. C. H. Lees (*Rec.*).
1906. York.....	Principal E. H. Griffiths, F.R.S.	Dr. L. N. G. Filon, Dr. J. A. Harker, A. R. Hinks, Prof. A. W. Porter (*Rec.*), H. Dennis Taylor.
1907. Leicester ...	Prof. A. E. H. Love, M.A., F.R.S.	E. E. Brooks, Dr. L. N. G. Filon, Dr. J. A. Harker, A. R. Hinks, Prof. A. W. Porter (*Rec.*).
1908. Dublin	Dr. W. N. Shaw, F.R.S.	Dr. W. G. Duffield, Dr. L. N. G. Filon, E. Gold, Prof. J. A. McClelland, Prof. A. W. Porter (*Rec.*), Prof. E. T. Whittaker.
1909. Winnipeg	Prof. E. Rutherford, F.R.S....	Prof. F. Allen, Prof. J. C. Fields, E. Gold, F. Horton, Prof. A. W. Porter (*Rec.*), Dr. A. A. Rambaut.
1910. Sheffield ...	Prof. E. W. Hobson, F.R.S....	H. Bateman, A. S. Eddington, E. Gold, Dr. F. Horton, Dr. S. R. Milner, Prof. A. W. Porter (*Rec.*).
1911. Portsmouth	Prof. H. H. Turner, F.R.S. ...	H. Bateman, Prof. P. V. Bevan, A. S. Eddington, E. Gold, Prof. A. W. Porter (*Rec.*), P. A. Yapp.
1912. Dundee ...	Prof. H. L. Callendar, F.R.S.	Prof. P. V. Bevan, E. Gold, Dr. H. B. Heywood, R. Norrie, Prof. A. W. Porter (*Rec.*), W. G. Robson, F. J. M. Stratton.
1913. Birmingham	Dr. H. F. Baker, F.R.S.	Prof. P. V. Bevan (*Rec.*), Prof. A. S. Eddington, E. Gold, Dr. H. B. Heywood, Dr. A. O. Rankine, Dr. G. A. Shakespear.
1914. Australia ...	Prof. F. T. Trouton, F.R.S....	Prof. A. S. Eddington (*Rec.*), E. Gold, Prof. T. R. Lyle, F.R.S., Prof. S. B. McLaren, Prof. J. A. Pollock, Dr. A. O. Rankine.

[1] Section A was constituted under this title in 1835, when the sectional division was introduced. The previous division was into 'Committees of Sciences.'

Date and Place	Presidents	Secretaries (*Rec.* = Recorder)
1915. Manchester	Sir F. W. Dyson, F.R.S. ...	Prof. A. S. Eddington, F.R.S. (*Rec.*), E. Gold, Dr. W. Makower, Dr. A. O. Rankine.
1916. Newcastle	Prof. A. N. Whitehead, F.R.S.	C. M. Caunt, Prof. A. S. Eddington, F.R.S. (*Rec.*), H. R. Hassé, Dr. W. Makower, Dr. A. O. Rankine.

SECTION B.[2]—CHEMISTRY.

1901. Glasgow ...	Prof. Percy F. Frankland, F.R.S.	W. C. Anderson, G. G. Henderson, W. J. Pope, T. K. Rose (*Rec.*).
1902. Belfast.....	Prof. E. Divers, F.R.S.....	R. F. Blake, M. O. Forster, Prof. G. G. Henderson, Prof. W. J. Pope (*Rec.*).
1903. Southport	Prof. W. N. Hartley, D.Sc., F.R.S.	Dr. M. O. Forster, Prof. G. G. Henderson, J. Ohm, Prof. W. J. Pope (*Rec.*).
1904. Cambridge	Prof. Sydney Young, F.R.S....	Dr. M. O. Forster, Prof. G. G. Henderson, Dr. H. O. Jones, Prof. W. J. Pope (*Rec.*).
1905. SouthAfrica	George T. Beilby	W. A. Caldecott, Mr. M. O. Forster, Prof. G. G. Henderson (*Rec.*), C. F. Juritz.
1906. York.....	Prof. Wyndham R. Dunstan, F.R.S.	Dr. E. F. Armstrong, Prof. A. W. Crossley, S. H. Davies, Prof. W. J. Pope (*Rec.*).
1907. Leicester ...	Prof. A. Smithells, F.R.S. ...	Dr. E. F. Armstrong, Prof. A. W. Crossley (*Rec.*), J. H. Hawthorn, Dr. F. M. Perkin.
1908. Dublin	Prof. F. S. Kipping, F.R.S. ...	Dr. E. F. Armstrong (*Rec.*), Dr. A. McKenzie, Dr. F. M. Perkin, Dr. J. H. Pollock.
1909. Winnipeg...	Prof. H. E. Armstrong, F.R.S.	Dr. E. F. Armstrong (*Rec.*), Dr. T. M. Lowry, Dr. F. M. Perkin, J. W. Shipley.
1910. Sheffield ...	J. E. Stead, F.R.S.	Dr. E. F. Armstrong (*Rec.*), Dr. T. M. Lowry, Dr. F. M. Perkin, W. E. S. Turner.
	Sub-section of Agriculture—A. D. Hall, F.R.S.	Dr. C. Crowther, J. Golding, Dr. E. J. Russell.
1911. Portsmouth	Prof. J. Walker, F.R.S.	Dr. E. F. Armstrong (*Rec.*), Dr. F. Beddow, Dr. C. H. Desch, Dr. T. M. Lowry.
1912. Dundee ...	Prof. A. Senier, M.D.	Dr. E. F. Armstrong (*Rec.*), Dr. C. H. Desch, Dr. A. Holt, Dr. J. K. Wood.
1913. Birmingham	Prof. W. P. Wynne, F.R.S. ...	Dr. E. F. Armstrong (*Rec.*), Dr. C. H. Desch, Dr. A. Holt, Dr. H. McCombie.
1914. Australia ...	Prof. W. J. Pope, F.R.S.	D. Avery, Prof. C. Fawsitt, Dr. A. Holt (*Rec.*), Dr. N. V. Sidgwick.
1915. Manchester	Prof. W. A. Bone, F.R.S. ...	Dr. H. F. Coward, Dr. C. H. Desch, Dr. A. Holt (*Rec.*).
1916. Newcastle	Prof. G. G. Henderson, F.R.S.	Dr. C. H. Desch, Dr. A. Holt (*Rec.*), Prof. R. Robinson, Dr. J. A. Smythe.

[2] 'Chemistry and Mineralogy,' 1835–1894.

Date and Place	Presidents	Secretaries (*Rec.* = Recorder)
SECTION C.[3]—GEOLOGY.		
1901. Glasgow ...	John Horne, F.R.S.	H. L. Bowman, H. W. Monckton (*Rec.*).
1902. Belfast.....	Lieut.-Gen. C. A. McMahon, F.R.S.	H. L. Bowman, H. W. Monckton (*Rec.*), J. St. J. Phillips, H. J. Seymour.
1903. Southport	Prof. W. W. Watts, M.A., M.Sc.	H. L. Bowman, Rev. W. L. Carter, J. Lomas, H. W. Monckton (*Rec.*).
1904. Cambridge	Aubrey Strahan, F.R.S.	H. L. Bowman (*Rec.*), Rev. W. L. Carter, J. Lomas, H. Woods.
1905. SouthAfrica	Prof. H. A. Miers, M.A., D.Sc., F.R.S.	H. L. Bowman (*Rec.*), J. Lomas, Dr. Molengraaff, Prof. A. Young, Prof. R. B. Young.
1906. York.....	G. W. Lamplugh, F.R.S.	H. L. Bowman (*Rec.*), Rev. W. L. Carter, Rev. W. Johnson, J. Lomas.
1907. Leicester...	Prof. J. W. Gregory, F.R.S....	Dr. F. W. Bennett, Rev. W. L. Carter, Prof. T. Groom, J. Lomas (*Rec.*).
1908. Dublin.....	Prof. John Joly, F.R.S.	Rev. W. L. Carter, J. Lomas (*Rec.*), Prof. S. H. Reynolds, H. J. Seymour.
1909. Winnipeg...	Dr. A. Smith Woodward, F.R.S.	W. L. Carter (*Rec.*), Dr. A. R. Dwerryhouse, R. T. Hodgson, Prof. S. H. Reynolds.
1910. Sheffield ...	Prof. A. P. Coleman, F.R.S...	W. L. Carter (*Rec.*), Dr. A. R. Dwerryhouse, B. Hobson, Prof. S. H. Reynolds.
1911. Portsmouth	A. Harker, F.R.S.	Col. C. W. Bevis, W. L. Carter (*Rec.*), Dr. A. R. Dwerryhouse, Prof. S. H. Reynolds.
1912. Dundee ...	Dr. B. N. Peach, F.R.S.	Prof. W. B. Boulton, A. W. R. Don, Dr. A. R. Dwerryhouse (*Rec.*), Prof. S. H. Reynolds.
1913. Birmingham	Prof. E. J. Garwood, M.A. ...	Prof. W. S. Boulton, Dr. A. R. Dwerryhouse (*Rec.*), F. Raw, Prof. S. H. Reynolds.
1914. Australia...	Prof. Sir T. H. Holland, F.R.S.	Dr. A. R. Dwerryhouse (*Rec.*), E. F. Pittman, Prof. S. H. Reynolds, Prof. E. W. Skeats.
1915. Manchester	Prof. Grenville A. J. Cole ...	W. Lower Carter (*Rec.*), Dr. W. T. Gordon, Dr. G. Hickling, Dr. D. M. S. Watson.
1916. Newcastle	Prof. W. S. Boulton	W. Lower Carter (*Rec.*), Dr. W. T. Gordon, Dr. G. Hickling, Dr. D. Woolacott.
SECTION D.[4]—ZOOLOGY.		
1901. Glasgow ...	Prof. J. Cossar Ewart, F.R.S.	J. G. Kerr (*Rec.*), J. Rankin, J. Y. Simpson.
1902. Belfast.....	Prof. G. B. Howes, F.R.S. ...	Prof. J. G. Kerr, R. Patterson, J. Y. Simpson (*Rec.*).
1903. Southport	Prof. S. J. Hickson, F.R.S. ...	Dr. J. H. Ashworth, J. Barcroft, A. Quayle, Dr. J. Y. Simpson (*Rec.*), Dr. H. W. M. Tims.

[3] 'Geology and Geography,' 1835–1850.

[4] 'Zoology and Botany,' 1835–1847; 'Zoology and Botany, including Physiology,' 1848–1865; 'Biology,' 1866–1894.

Date and Place	Presidents	Secretaries (*Rec.* = Recorder)
1904. Cambridge	William Bateson, F.R.S.	Dr. J. H. Ashworth, L. Doncaster, Prof. J. Y. Simpson (*Rec.*), Dr. H. W. M. Tims.
1905. SouthAfrica	G. A. Boulenger, F.R.S.	Dr. Pakes, Dr. Purcell, Prof. J. Y. Simpson (*Rec.*), Dr. H. W. M. Tims.
1906. York.....	J. J. Lister, F.R.S.	Dr. J. H. Ashworth, L. Doncaster, Oxley Grabham, Dr. H. W. M. Tims (*Rec.*).
1907. Leicester ...	Dr. W. E. Hoyle, M.A.....	Dr. J. H. Ashworth, L. Doncaster, E. E. Lowe, Dr. H. W. M. Tims (*Rec.*).
1908. Dublin.....	Dr. S. F. Harmer, F.R.S.....	Dr. J. H. Ashworth, L. Doncaster, Prof. A. Fraser, Dr. H. W. M. Tims (*Rec.*).
1909. Winnipeg...	Dr. A. E. Shipley, F.R.S. ...	C. A. Baragar, C. L. Boulenger, Dr. J. Pearson, Dr. H. W. M. Tims (*Rec.*).
1910. Sheffield ...	Prof. G. C. Bourne, F.R.S. ...	Dr. J. H. Ashworth, L. Doncaster, T. J. Evans, Dr. H. W. M. Tims (*Rec.*).
1911. Portsmouth	Prof. D'Arcy W. Thompson, C.B.	Dr. J. H. Ashworth, C. Foran, R. D. Laurie, Dr. H. W. M. Tims (*Rec.*).
1912. Dundee ...	Dr. P. Chalmers Mitchell, F.R.S.	Dr. J. H. Ashworth, R. D. Laurie, Miss D. L. Mackinnon, Dr. H. W. M. Tims (*Rec.*).
1913. Birmingham	Dr. H. F. Gadow, F.R.S.....	Dr. J. H. Ashworth, Dr. C. L. Boulenger, R. D. Laurie, Dr. H. W. M. Tims (*Rec.*).
1914. Australia ...	Prof. A. Dendy, F.R.S.....	Dr. J. H. Ashworth, Dr. T. S. Hall, Prof. W. A. Haswell, R. D. Laurie, Prof. H. W. Marett Tims (*Rec.*).
1915. Manchester	Prof. E. A. Minchin, F.R.S....	Dr. J. H. Ashworth (*Rec.*), F. Balfour Browne, R. D. Laurie, Dr. J. Stuart Thomson.
1916. Newcastle	Prof. E. W. MacBride, F.R.S.	Dr. J. H. Ashworth (*Rec.*), R. A. H. Gray, R. D. Laurie.

SECTION E.[5]—GEOGRAPHY.

1901. Glasgow ...	Dr. H. R. Mill, F.R.G.S.	H. N. Dickson (*Rec.*), E. Heawood, G. Sandeman, A. C. Turner.
1902. Belfast.....	Sir T. H. Holdich, K.C.B. ...	G. G. Chisholm (*Rec.*), E. Heawood, Dr. A. J. Herbertson, Dr. J. A. Lindsay.
1903. Southport...	Capt. E. W. Creak, R.N., C.B., F.R.S.	E. Heawood (*Rec.*), Dr. A. J. Herbertson, E. A. Reeves, Capt. J. C. Underwood.
1904. Cambridge	Douglas W. Freshfield.....	E. Heawood (*Rec.*), Dr. A. J. Herbertson, H. Y. Oldham, E. A. Reeves.
1905. SouthAfrica	Adm. Sir W. J. L. Wharton, R.N., K.C.B., F.R.S.	A. H. Cornish-Bowden, F. Flowers, Dr. A. J. Herbertson (*Rec.*), H. Y. Oldham.
1906. York.	Rt. Hon. Sir George Goldie, K.C.M.G., F.R.S.	E. Heawood (*Rec.*), Dr. A. J. Herbertson, E. A. Reeves, G. Yeld.

[5] Section E was that of 'Anatomy and Medicine,' 1835; of 'Medical Science, 1836–44; of 'Physiology' (afterwards incorporated in Section D), 1844–1847. It was assigned to 'Geography and Ethnology,' 1851–1868; 'Geography,' 1869.

Date and Place	Presidents	Secretaries (*Rec.* = Recorder)
1907. Leicester ..	George G. Chisholm, M.A. ...	E. Heawood (*Rec.*), O. J. R. Howarth, E. A. Reeves, T. Walker.
1908. Dublin	Major E. H. Hills, C.M.G., R.E.	W. F. Bailey, W. J. Barton, O. J. P. Howarth (*Rec.*), E. A. Reeves.
1909. Winnipeg...	Col. Sir D. Johnston, K.C.M.G., C.B., R.E.	G. G. Chisholm (*Rec.*), J. McFarlane, A. McIntyre.
1910. Sheffield ...	Prof. A. J. Herbertson, M.A., Ph.D.	Rev. W. J. Barton (*Rec.*), Dr. R. Brown, J. McFarlane, E. A. Reeves.
1911. Portsmouth	Col. C. F. Close, R.E., C.M.G.	J. McFarlane (*Rec.*), E. A. Reeves, W. P. Smith.
1912. Dundee ...	Col. Sir C. M. Watson, K.C.M.G.	Rev. W. J. Barton (*Rec.*), J. McFarlane, E. A. Reeves, D. Wylie.
1913. Birmingham	Prof. H. N. Dickson, D.Sc. ...	Rev. W. J. Barton (*Rec.*), P. E. Martineau, J. McFarlane, E. A. Reeves.
1914. Australia ...	Sir C. P. Lucas, K.C.B., K.C.M.G.	J. A. Leach, J. McFarlane, H. Yule Oldham (*Rec.*), F. Poate.
1915. Manchester	Major H. G. Lyons, F.R.S. ...	Dr. R. N. Rudmose Brown, J. McFarlane (*Rec.*).
1916. Newcastle	E. A. Reeves	Dr. R. N. Rudmose Brown, J. McFarlane (*Rec.*), H. Shaw, B. C. Wallis.

SECTION F.[6]—ECONOMIC SCIENCE AND STATISTICS.

1901. Glasgow ...	Sir R. Giffen, K.C.B., F.R.S.	W. W. Blackie, A. L. Bowley, E. Cannan (*Rec.*), S. J. Chapman.
1902. Belfast ...	E. Cannan, M.A., LL.D.	A. L. Bowley (*Rec.*), Prof. S. J. Chapman, Dr. A. Duffin.
1903. Southport	E. W. Brabrook, C.B.	A. L. Bowley (*Rec.*), Prof. S. J. Chapman, Dr. B. W. Ginsburg, G. Lloyd.
1904. Cambridge	Prof. Wm. Smart, LL.D.	J. E. Bidwell, A. L. Bowley (*Rec.*), Prof. S. J. Chapman, Dr. B. W. Ginsburg.
1905. SouthAfrica	Rev. W. Cunningham, D.D., D.Sc.	R. à Ababrelton, A. L. Bowley (*Rec.*), Prof. H. E. S. Fremantle, H. O. Meredith.
1906. York.....	A. L. Bowley, M.A.	Prof. S. J. Chapman (*Rec.*), D. H. Macgregor, H. O. Meredith, B. S. Rowntree.
1907. Leicester ...	Prof. W. J. Ashley, M.A.....	Prof. S. J. Chapman (*Rec.*), D. H. Macgregor, H. O. Meredith, T. S. Taylor.
1908. Dublin.....	W. M. Acworth, M.A.	W. G. S. Adams, Prof. S. J. Chapman (*Rec.*), Prof. D. H. Macgregor, H. O. Meredith.
	Sub-section of Agriculture—Rt. Hon. Sir H. Plunkett.	A. D. Hall, Prof. J. Percival, J. H. Priestley, Prof. J. Wilson.
1909. Winnipeg...	Prof. S. J. Chapman, M.A. ...	Prof. A. B. Clark, Dr. W. A. Manahan, Dr. W. R. Scott (*Rec.*).
1910. Sheffield ...	Sir H. Llewellyn Smith, K.C.B., M.A.	C. R. Fay, H. O. Meredith (*Rec.*), Dr. W. R. Scott, R. Wilson.
1911. Portsmouth	Hon. W. Pember Reeves	C. R. Fay, Dr. W. R. Scott (*Rec.*), H. A. Stibbs.
1912. Dundee ...	Sir H. H. Cunynghame, K.C.B.	C. R. Fay, Dr. W. R. Scott (*Rec.*), E. Tosh.

[6] 'Statistics,' 1835–1855.

Date and Place	Presidents	Secretaries (*Rec.* = Recorder)
1913. Birmingham	Rev. P. H. Wicksteed, M.A.	C. R. Fay, Prof. A. W. Kirkaldy, Prof. H. O. Meredith, Dr. W. R. Scott (*Rec.*).
1914. Australia ...	Prof. E. C. K. Gonner	Prof. R. F. Irvine, Prof. A. W. Kirkaldy (*Rec.*), G. H. Knibbs, Prof. H. O. Meredith.
1915. Manchester	Prof. W. R. Scott	B. Ellinger, E. J. W. Jackson, Prof. A. W. Kirkaldy (*Rec.*).
1916. Newcastle	Prof. A. W. Kirkaldy	Miss Ashley (*Rec.*), J. Cunnison, C. R. Fay, Prof. H. M. Hallsworth E. J. W. Jackson.

SECTION G.[7]—ENGINEERING.

1901. Glasgow ...	R. E. Crompton, M.Inst.C.E.	H. Bamford, W. E. Dalby, W. A. Price (*Rec.*).
1902. Belfast ...	Prof. J. Perry, F.R.S.	M. Barr, W. A. Price (*Rec.*), J. Wylie.
1903. Southport	C. Hawksley, M.Inst.C.E. ...	Prof. W. E. Dalby, W. T. Maccall, W. A. Price (*Rec.*).
1904. Cambridge	Hon. C. A. Parsons, F.R.S. ...	J. B. Peace, W. T. Maccall, W. A. Price (*Rec.*).
1905. SouthAfrica	Col. Sir C. Scott-Moncrieff, G.C.S.I., K.C.M.G., R.E.	W. T. Maccall, W. B. Marshall (*Rec.*), Prof. H. Payne, E. Williams.
1906. York.....	J. A. Ewing, F.R.S.	W. T. Maccall, W. A. Price (*Rec.*), J. Triffit.
1907. Leicester ...	Prof. Silvanus P. Thompson, F.R.S.	Prof. E. G. Coker, A. C. Harris, W. A. Price (*Rec.*), H. E. Wimperis.
1908. Dublin	Dugald Clerk, F.R.S.	Prof. E. G. Coker, Dr. W. E. Lilly, W. A. Price (*Rec.*), H. E. Wimperis.
1909. Winnipeg...	Sir W. H. White, K.C.B., F.R.S.	E. E. Brydone-Jack, Prof. E. G. Coker, Prof. E. W. Marchant, W. A. Price (*Rec.*).
1910. Sheffield ..	Prof. W. E. Dalby, M.A., M.Inst.C.E.	F. Boulden, Prof. E. G. Coker (*Rec.*), A. A. Rowse, H. E. Wimperis.
1911. Portsmouth	Prof. J. H. Biles, LL.D., D.Sc.	H. Ashley, Prof. E. G. Coker (*Rec.*), A. A. Rowse, H. E. Wimperis.
1912. Dundee ...	Prof. A. Barr, D.Sc.....	Prof. E. G. Coker (*Rec.*), A. R. Fulton, H. Richardson, A. A. Rowse, H. E. Wimperis.
1913. Birmingham	Prof. Gisbert Kapp, D.Eng....	Prof. E. G. Coker (*Rec.*), J. Purser, A. A. Rowse, H. E. Wimperis.
1914. Australia ...	Prof. E. G. Coker, D.Sc.....	Prof. G. W. O. Howe (*Rec.*), Prof. H. Payne, Prof. W. M. Thornton, Prof. W. H. Warren.
1915. Manchester	Dr. H. S. Hele-Shaw, F.R.S.	Dr. W. Cramp, J. Frith, Prof. G. W. O. Howe (*Rec.*).
1916. Newcastle	G. G. Stoney, F.R.S.....	Prof. G. W. O. Howe (*Rec.*), Prof. E. W. Marchant, Prof. W. M. Thornton.

SECTION H.[8]—ANTHROPOLOGY.

1901. Glasgow ...	Prof. D. J. Cunningham, F.R.S.	W. Crooke, Prof. A. F. Dixon, J. F. Gemmill, J. L. Myres (*Rec.*).
1902. Belfast ...	Dr. A. C. Haddon, F.R.S. ...	R. Campbell, Prof. A. F. Dixon, J. L. Myres (*Rec.*).

[7] 'Mechanical Science,' 1836–1900.

[8] Established 1884.

Date and Place	Presidents	Secretaries (*Rec.* = Recorder)
1903. Southport...	Prof. J. Symington, F.R.S. ...	E. N. Fallaize, H. S. Kingsford, E. M. Littler, J. L. Myres (*Rec.*).
1904. Cambridge	H. Balfour, M.A.	W. L. H. Duckworth, E. N. Fallaize, H. S. Kingsford, J. L. Myres (*Rec.*).
1905. SouthAfrica	Dr. A. C. Haddon, F.R.S. ...	A. R. Brown, A. von Dessauer, E. S. Hartland (*Rec.*).
1906. York.....	E. Sidney Hartland, F.S.A....	Dr. G. A. Auden, E. N. Fallaize (*Rec.*), H. S. Kingsford, Dr. F. C. Shrubsall.
1907. Leicester ..	D. G. Hogarth, M.A.....	C. J. Billson, E. N. Fallaize (*Rec.*), H. S. Kingsford, Dr. F. C. Shrubsall.
1908. Dublin	Prof. W. Ridgeway, M.A. ...	E. N. Fallaize (*Rec.*), H. S. Kingsford, Dr. F. C. Shrubsall, L. E. Steele.
1909. Winnipeg...	Prof. J. L. Myres, M.A.	H. S. Kingsford (*Rec.*), Prof. C. J. Patten, Dr. F. C. Shrubsall.
1910. Sheffield ...	W. Crooke, B.A.	E. N. Fallaize (*Rec.*), H. S. Kingsford, Prof. C. J. Patten, Dr. F. C. Shrubsall.
1911. Portsmouth	W. H. R. Rivers, M.D., F.R.S.	E. N. Fallaize (*Rec.*), H. S. Kingsford, E. W. Martindell, H. Rundle, Dr. F. C. Shrubsall.
1912. Dundee ...	Prof. G. Elliot Smith, F.R.S.	D. D. Craig, E. N. Fallaize (*Rec.*), E. W. Martindell, Dr. F. C. Shrubsall.
1913. Birmingham	Sir Richard Temple, Bart. ...	E. N. Fallaize (*Rec.*), E. W. Martindell, Dr. F. C. Shrubsall, T. Yeates.
1914. Australia ...	Sir E. F. im Thurn, C.B., K.C.M.G.	Prof. R. J. A. Berry, Dr. B. Malinowski, Dr. R. R. Marett (*Rec.*), Prof. J. T. Wilson.
1915. Manchester	Prof. C. G. Seligman	E. N. Fallaize (*Rec.*), Dr. F. C. Shrubsall, J. S. B. Stopford.
1916. Newcastle	Dr. R. R. Marett	Rev. E. O. James, Dr F. S. Shrubsall (*Rec.*), E. P. Stibbe.

SECTION I.[9]—PHYSIOLOGY (including Experimental Pathology and Experimental Psychology).

1901. Glasgow ...	Prof. J. G. McKendrick, F.R.S.	W. B. Brodie, W. A. Osborne, Prof. W. H. Thompson (*Rec.*).
1902. Belfast ...	Prof. W. D. Halliburton, F.R.S.	J. Barcroft, Dr. W. A. Osborne (*Rec.*), Dr. C. Shaw.
1904. Cambridge	Prof. C. S. Sherrington, F.R.S.	J. Barcroft (*Rec.*), Prof. T. G. Brodie, Dr. L. E. Shore.
1905. SouthAfrica	Col. D. Bruce, C.B., F.R.S. ...	J. Barcroft (*Rec.*), Dr. Baumann, Dr. Mackenzie, Dr. G. W. Robertson, Dr. Stanwell.
1906. York.....	Prof. F. Gotch, F.R.S.	J. Barcroft (*Rec.*), Dr. J. M. Hamill, Dr. D. S. Long, Prof. J. S. Macdonald.
1907. Leicester ...	Dr. A. D. Waller, F.R.S.	Dr. N. H. Alcock, J. Barcroft (*Rec.*), Prof. J. S. Macdonald, Dr. A. Warner.

[9] Established 1894.

Date and Place	Presidents	Secretaries (*Rec.*=Recorder)
1908. Dublin.....	Dr. J. Scott Haldane, F.R.S.	Prof. D. J. Coffey, Dr. P. T. Herring, Prof. J. S. Macdonald, Dr. H. E. Roaf (*Rec.*).
1909. Winnipeg...	Prof. E. H. Starling, F.R.S....	Dr. N. H. Alcock (*Rec.*), Prof. P. T. Herring, Dr. W. Webster.
1910. Sheffield ...	Prof. A. B. Macallum, F.R.S.	Dr. H. G. M. Henry, Keith Lucas, Dr. H. E. Roaf (*Rec.*), Dr. J. Tait.
1911. Portsmouth	Prof. J. S. Macdonald, B.A.	Dr. J. T. Leon, Dr. Keith Lucas, Dr. H. E. Roaf (*Rec.*), Dr. J. Tait.
1912. Dundee ...	Leonard Hill, F.R.S.	Dr. Keith Lucas, W. Moodie, Dr. H. E. Roaf (*Rec.*), Dr. J. Tait.
1913. Birmingham	Dr. F. Gowland Hopkins, F.R.S.	C. L. Burt, Prof. P. T. Herring, Dr. T. G. Maitland, Dr. H. E. Roaf (*Rec.*), Dr. J. Tait.
1914. Australia...	Prof. B. Moore, F.R.S.	Prof. P. T. Herring (*Rec.*), Prof. T. H. Milroy, Prof. W. A. Osborne, Prof. Sir T. P. Anderson Stuart.
1915. Manchester	Prof. W. M. Bayliss, F.R.S.	C. L. Burt, Prof. P. T. Herring (*Rec.*), Dr. F. W. Lamb, Dr. J. Tait.
1916. Newcastle	Prof. A. R. Cushny, F.R.S. ...	C. L. Burt, Prof. P. T. Herring(*Rec.*), Prof. J. A. Menzies.

SECTION K.[10]—BOTANY.

1901. Glasgow ...	Prof. I. B. Balfour, F.R.S. ...	D. T. Gwynne-Vaughan, G. F. Scott Elliot, A. C. Seward (*Rec.*), H. Wager.
1902. Belfast ...	Prof. J. R. Green, F.R.S.	A. G. Tansley, Rev. C. H. Waddell, H. Wager (*Rec.*), R. H. Yapp.
1903. Southport	A. C. Seward, F.R.S.	H. Ball, A. G. Tansley, H. Wager (*Rec.*), R. H. Yapp.
1904. Cambridge	Francis Darwin, F.R.S. ..... *Sub-section of Agriculture*—Dr. W. Somerville.	Dr. F. F. Blackman, A. G. Tansley, H. Wager (*Rec.*), T. B. Wood, R. H. Yapp.
1905. SouthAfrica	Harold Wager, F.R.S.	R. P. Gregory, Dr. Marloth, Prof. Pearson, Prof. R. H. Yapp (*Rec.*).
1906. York.....	Prof. F. W. Oliver, F.R.S. ...	Dr. A. Burtt, R. P. Gregory, Prof. A. G. Tansley (*Rec.*), Prof. R. H. Yapp.
1907. Leicester...	Prof. J. B. Farmer, F.R.S. ...	W. Bell, R. P. Gregory, Prof. A. G. Tansley (*Rec.*), Prof. R. H. Yapp.
1908. Dublin.....	Dr. F. F. Blackman, F.R.S....	Prof. H. H. Dixon, R. P. Gregory, A. G. Tansley (*Rec.*), Prof. R. H. Yapp.
1909. Winnipeg...	Lieut.-Col. D. Prain, C.I.E., F.R.S.	Prof. A. H. R. Buller, Prof. D. T. Gwynne-Vaughan, Prof. R. H. Yapp (*Rec.*).
	Sub-section of Agriculture—Major P. G. Craigie, C.B.	W. J. Black, Dr. E. J. Russell, Prof. J. Wilson.
1910. Sheffield ...	Prof. J. W. H. Trail, F.R.S.	B. H. Bentley, R. P. Gregory, Prof. D. T. Gwynne-Vaughan, Prof. R. H. Yapp (*Rec.*).
1911. Portsmouth	Prof. F. E. Weiss, D.Sc.	C. G. Delahunt, Prof. D. T. Gwynne-Vaughan, Dr. C. E. Moss, Prof. R. H. Yapp (*Rec.*).

[10] Established 1895.

Date and Place	Presidents	Secretaries (*Rec.* = Recorder)
	Sub-section of Agriculture—W. Bateson, M.A., F.R.S.	J. Golding, H. R. Pink, Dr. E. J. Russell.
1912. Dundee ...	Prof. F. Keeble, D.Sc.	J. Brebner, Prof. D. T. Gwynne-Vaughan (*Rec.*), Dr. C. E. Moss, D. Thoday.
1913. Birmingham	Miss Ethel Sargant, F.L.S. ..	W. B. Grove, Prof. D. T. Gwynne-Vaughan (*Rec.*), Dr. C. E. Moss, D. Thoday.
1914. Australia ...	Prof. F. O. Bower, F.R.S. ...	Prof. A. J. Ewart, Prof. T. Johnson (*Rec.*), Prof. A. A. Lawson, Miss E. N. Thomas.
1915. Manchester	Prof. W. H. Lang, F.R.S. ...	R. S. Adamson, Dr. C. E. Moss (*Rec.*), D. Thoday.
1916. Newcastle	Dr. A. B. Rendle, F.R.S.	R. C. Davie, J. Small, D. Thoday (*Rec.*), Dr. Ethel Thomas.

SECTION L.—EDUCATIONAL SCIENCE.

1901. Glasgow ...	Sir John E. Gorst, F.R.S. ...	R. A. Gregory, W. M. Heller, R. Y. Howie, C. W. Kimmins, Prof. H. L. Withers (*Rec.*).
1902. Belfast ...	Prof. H. E. Armstrong, F.R.S.	Prof. R. A. Gregory, W. M. Heller (*Rec.*), R. M. Jones, Dr. C. W. Kimmins, Prof. H. L. Withers.
1903. Southport ..	Sir W. de W. Abney, K.C.B., F.R.S.	Prof. R. A. Gregory, W. M. Heller (*Rec.*), Dr. C. W. Kimmins, Dr. H. L. Snape.
1904. Cambridge	Bishop of Hereford, D.D. ...	J. H. Flather, Prof. R. A. Gregory, W. M. Heller (*Rec.*), Dr. C. W. Kimmins.
1905. SouthAfrica	Prof. Sir R. C. Jebb, D.C.L., M.P.	A. D. Hall, Prof. Hele-Shaw, Dr. C. W. Kimmins (*Rec.*), J. R. Whitton.
1906. York.....	Prof. M. E. Sadler, LL.D. ...	Prof. R. A. Gregory, W. M. Heller (*Rec.*), Hugh Richardson.
1907. Leicester ...	Sir Philip Magnus, M.P.	W. D. Eggar, Prof. R. A. Gregory (*Rec.*), J. S. Laver, Hugh Richardson.
1908. Dublin	Prof. L. C. Miall, F.R.S.	Prof. E. P. Culverwell, W. D. Eggar, George Fletcher, Prof. R. A. Gregory (*Rec.*), Hugh Richardson.
1909. Winnipeg...	Rev. H. B. Gray, D.D.	W. D. Eggar, R. Fletcher, J. L. Holland (*Rec.*), Hugh Richardson.
1910. Sheffield ...	Principal H. A. Miers, F.R.S.	A. J. Arnold, W. D. Eggar, J. L. Holland (*Rec.*), Hugh Richardson.
1911. Portsmouth	Rt. Rev. J. E. C. Welldon, D.D.	W. D. Eggar, O. Freeman, J. L. Holland (*Rec.*), Hugh Richardson.
1912. Dundee ...	Prof. J. Adams, M.A.	D. Berridge, Dr. J. Davidson, Prof. J. A. Green (*Rec.*), Hugh Richardson.
1913. Birmingham	Principal E. H. Griffiths, F.R.S.	D. Berridge, Rev. S. Blofeld, Prof. J. A. Green (*Rec.*), H. Richardson.
1914. Australia ...	Prof. J. Perry, F.R.S.	P. Board, C. A. Buckmaster, Prof. J. A. Green (*Rec.*), J. Smyth.
1915. Manchester	Mrs. Henry Sidgwick	D. Berridge, F. A. Bruton, Prof. J. A. Green (*Rec.*), H. Richardson.
1916. Newcastle	Rev. W. Temple	D. Berridge, Prof. J. A. Green (*Rec.*), P. Sharp, Dr. E. H. Tripp.

Date and Place	Presidents	Secretaries (*Rec.* = Recorder)
SECTION M.—AGRICULTURE.		
1912. Dundee ...	T. H. Middleton, M.A.....	Dr. C. Crowther, J. Golding, Dr. A. Lauder, Dr. E. J. Russell (*Rec.*).
1913. Birmingham	Prof. T. B. Wood, M.A.	W. E. Collinge, Dr. C. Crowther, J. Golding, Dr. E. J. Russell (*Rec.*).
1914. Australia ...	A. D. Hall, F.R.S.....	Prof. T. Cherry, J. Golding (*Rec.*), Dr. A. Lauder, Prof. R. D. Watt.
1915. Manchester	R. H. Rew, C.B.	Prof. C. Crowther (*Rec.*), Dr. A. Lauder, T. J. Young.
1916. Newcastle	Dr. E. J. Russell	S. H. Collins, Prof. C. Crowther (*Rec.*), Dr. A. Lauder.

EVENING DISCOURSES, 1901-16.

(For 1919, see *General Meetings*, p. xlii.)

Date and Place	Lecturer	Subject of Discourse
1901. Glasgow ...	Prof. W. Ramsay, F.R.S.	The Inert Constituents of the Atmosphere.
	Francis Darwin, F.R.S.	The Movements of Plants.
1902. Belfast ...	Prof. J. J. Thomson, F.R.S....	Becquerel Rays and Radio-activity.
	Prof. W. F. R. Weldon, F.R.S.	Inheritance.
1903. Southport...	Dr. R. Munro	Man as Artist and Sportsman in the Palæolithic Period.
	Dr. A. Rowe	The Old Chalk Sea, and some of its Teachings.
1904. Cambridge	Prof. G. H. Darwin, F.R.S....	Ripple-Marks and Sand-Dunes.
	Prof. H. F. Osborn	Palæontological Discoveries in the Rocky Mountains.
1905. S. Africa: Cape Town ...	Prof. E. B. Poulton, F.R.S. ...	W. J. Burchell's Discoveries in South Africa.
	C. Vernon Boys, F.R.S.	Some Surface Actions of Fluids.
Durban ...	Douglas W. Freshfield.....	The Mountains of the Old World.
	Prof. W. A. Herdman, F.R.S.	Marine Biology.
Pietermaritz-burg.	Col. D. Bruce, C.B., F.R.S....	Sleeping Sickness.
	H. T. Ferrar	The Cruise of the 'Discovery.'
Johannesburg	Prof. W. E. Ayrton, F.R.S. ...	The Distribution of Power.
	Prof. J. O. Arnold.....	Steel as an Igneous Rock.
Pretoria ...	A. E. Shipley, F.R.S.	Fly-borne Diseases: Malaria, Sleeping Sickness, &c.
Bloemfontein...	A. R. Hinks	The Milky Way and the Clouds of Magellan.
Kimberley ...	Sir Wm. Crookes, F.R.S.	Diamonds.
	Prof. J. B. Porter	The Bearing of Engineering on Mining.
Bulawayo ...	D. Randall-MacIver	The Ruins of Rhodesia.
1906. York.....	Dr. Tempest Anderson.....	Volcanoes.
	Dr. A. D. Waller, F.R.S.	The Electrical Signs of Life, and their Abolition by Chloroform.
1907. Leicester ...	W. Duddell, F.R.S.	The Ark and the Spark in Radio-telegraphy.
	Dr. F. A. Dixey.....	Recent Developments in the Theory of Mimicry.
1908. Dublin	Prof. H. H. Turner, F.R.S. ...	Halley's Comet.
	Prof. W. M. Davis	The Lessons of the Colorado Canyon.

Date and Place	Lecturer	Subject of Discourse
1909. Winnipeg...	Dr. A. E. H. Tutton, F.R.S....	The Seven Styles of Crystal Architecture.
	Prof. W. A. Herdman, F.R.S.	Our Food from the Waters.
	[1] Prof. H. B. Dixon, F.R.S. ...	The Chemistry of Flame.
	[1] Prof. J. H. Poynting, F.R.S.	The Pressure of Light.
1910. Sheffield ...	Prof. W. Stirling, M.D.	Types of Animal Movement.[2]
	D. G. Hogarth	New Discoveries about the Hittites.
1911. Portsmouth	Dr. Leonard Hill, F.R.S.....	The Physiology of Submarine Work.
	Prof. A. C. Seward, F.R.S. ...	Links with the Past in the Plant World.
1912. Dundee ...	Prof. W. H. Bragg, F.R.S. ...	Radiations, Old and New.
	Prof. A. Keith, M.D.....	The Antiquity of Man.
1913. Birmingham	Sir H. H. Cunynghame, K.C.B.	Explosions in Mines and the Means of Preventing Them.
	Dr. A. Smith Woodward, F.R.S.	Missing Links among Extinct Animals.
1914. Australia:		
Adelaide	Sir Oliver J. Lodge, F.R.S....	The Ether of Space.
	Prof. W. J. Sollas, F.R.S. ...	Ancient Hunters.
Melbourne	Prof. E. B. Poulton, F.R.S....	Mimicry.
	Dr. F. W. Dyson, F.R.S. ...	Greenwich Observatory.
Sydney ...	Prof. G. Elliot Smith, F.R.S.	Primitive Man.
	Sir E. Rutherford, F.R.S. ...	Atoms and Electrons.
Brisbane	Prof. H. E. Armstrong, F.R.S.	The Materials of Life.
	Prof. G. W. O. Howe	Wireless Telegraphy.
	Sir E. A. Schäfer, F.R.S.....	Australia and the British Association.
1915. Manchester	H. W. T. Wager, F.R.S.	The Behaviour of Plants in Response to Light.
	Prof. R. A. Sampson, F.R.S.	A Census of the Skies.
1916. Newcastle	Prof. W. A. Bone, F.R.S.	Flame and Flameless Combustion.
	Dr. P. Chalmers Mitchell, F.R.S.	Evolution and the War.

PUBLIC OR CITIZENS' LECTURES, 1912–16.

(For 1919, see p. lxxv.)

Date and Place	Lecturer	Subject of Lecture
1912. Dundee ...	Prof. B. Moore, D.Sc.	Science and National Health.
	Prof. E. C. K. Gonner, M.A.	Prices and Wages.
	Prof. A. Fowler, F.R.S.	The Sun.
1913. Birmingham	Dr. A. C. Haddon, F.R.S. ...	The Decorative Art of Savages.
	Dr. Vaughan Cornish	The Panama Canal.
	Leonard Doncaster, M.A. ...	Recent Work on Heredity and its Application to Man.
	Dr. W. Rosenhain, F.R.S. ...	Metals under the Microscope.
	Frederick Soddy, F.R.S.	The Evolution of Matter.
1914. Australia:		
Perth ...	Prof. W. A. Herdman, F.R.S.	Why we Investigate the Ocean.
	Prof. A. S. Eddington, F.R.S.	Stars and their Movements.
	H. Balfour, M.A.	Primitive Methods of Making Fire.
	Prof. A. D. Waller, F.R.S. ...	Electrical Action of the Human Heart.

[1] 'Popular Lectures,' delivered to the citizens of Winnipeg.
[2] Repeated, to the public, on Wednesday, September 7.

Date and Place	Lecturer	Subject of Lecture
Kalgoorlie	C. A. Buckmaster, M.A.	Mining Education in England.
Adelaide	Prof. E. C. K. Gonner, M.A.	Saving and Spending.
Melbourne	Dr. W. Rosenhain, F.R.S. ...	Making of a Big Gun.
	Prof. H. B. Dixon, F.R.S. ...	Explosions.
Sydney ...	Prof. B. Moore, F.R.S.....	Brown Earth and Bright Sunshine.
	Prof. H. H. Turner, P.R.S. ...	Comets.
Brisbane	Dr. A. C. Haddon, F.R.S. ...	Decorative Art in Papua.
1915. Manchester and Neighbourhood	Prof. F. W. Gamble, F.R.S.	Evolution and War.
	Dr. Vaughan Cornish	Strategic Geography of the War.
	Dr. W. Rosenhain, F.R.S. ...	Making of a Big Gun.
	Prof. W. Stirling	Curiosities and Defects of Sight.
	A. R. Hinks, F.R.S.	Daily Uses of Astronomy.
	Prof. B. Moore, F.R.S.....	Health Conditions in the Modern Workshop.
	Rev. A. L. Cortie	Formation of the Sun and Stars.
	Prof. H. H. Turner, F.R.S. ...	Some Lessons from Astronomy.
1916. Newcastle and Neighbourhood:		
Newcastle	Dr. Dugald Clerk, F.R.S. ...	Gas, Oil and Petrol Engines.
	A. L. Smith, M.A.....	Education after the War.
Sunderland	Dr. F. A. Dixey.....	Warfare in Nature.
Durham ...	Prof. J. W. Gregory	The Evolution of Geography.
Ashington...	Prof. A. W. Kirkcaldy	The Economic Outlook after the War.

CHAIRMEN, PRESIDENT, AND SECRETARIES OF THE CONFERENCES OF DELEGATES OF CORRESPONDING SOCIETIES, 1901–16.[1]

(For 1919, see p. xliv.)

Date and Place	Chairmen	Secretaries
1901. Glasgow ...	F. W. Rudler, F.G.S.	Dr. J. G. Garson, A. Somerville.
1902. Belfast.....	Prof. W. W. Watts, F.G.S. ...	E. J. Bles.
1903. Southport ..	W. Whitaker, F.R.S.	F. W. Rudler.
1904. Cambridge	Prof. E. H. Griffiths, F.R.S.	F. W. Rudler.
1905. London ...	Dr. A. Smith Woodward, F.R.S.	F. W. Rudler.
1906. York.....	Sir Edward Brabrook, C.B....	F. W. Rudler.
1907. Leicester...	H. J. Mackinder, M.A.....	F. W. Rudler, I.S.O.
1908. Dublin	Prof. H. A. Miers, F.R.S.....	W. P. D. Stebbing.
1909. London ...	Dr. A. C. Haddon, F.R.S. ...	W. P. D. Stebbing.
1910. Sheffield ...	Dr. Tempest Anderson.....	W. P. D. Stebbing.
1911. Portsmouth	Prof. J. W. Gregory, F.R.S....	W. P. D. Stebbing.
1912. Dundee ...	Prof. F. O. Bower, F.R.S. ...	W. P. D. Stebbing.
1913. Birmingham	Dr. P. Chalmers Mitchell, F.R.S.	W. P. D. Stebbing.
1914. Le Havre...	Sir H. George Fordham ...	W. Mark Webb.
1915. Manchester	Sir T. H. Holland, F.R.S. ...	W. Mark Webb.
	President.	
1916. Newcastle	Prof. G. A. Lebour	W. Mark Webb.

[1] Established 1885.

General Statement of Sums which have been paid on account of Grants for Scientific Purposes, 1901-1918.

1901.	£	s.	d.
Electrical Standards	45	0	0
Seismological Observations	75	0	0
Wave-length Tables	4	14	0
Isomorphous Sulphonic Derivatives of Benzene	35	0	0
Life-zones in British Carboniferous Rocks	20	0	0
Underground Water of North-West Yorkshire	50	0	0
Exploration of Irish Caves	15	0	0
Table at the Zoological Station, Naples	100	0	0
Table at the Biological Laboratory, Plymouth	20	0	0
Index Generum et Specierum Animalium	75	0	0
Migration of Birds	10	0	0
Terrestrial Surface Waves	5	0	0
Changes of Land-level in the Phlegræan Fields	50	0	0
Legislation regulating Women's Labour	15	0	0
Small Screw Gauge	45	0	0
Resistance of Road Vehicles to Traction	75	0	0
Silchester Excavation	10	0	0
Ethnological Survey of Canada	30	0	0
Anthropological Teaching	5	0	0
Exploration in Crete	145	0	0
Physiological Effects of Peptone	30	0	0
Chemistry of Bone Marrow	5	15	11
Suprarenal Capsules in the Rabbit	5	0	0
Fertilisation in Phæophyceæ	15	0	0
Morphology, Ecology, and Taxonomy of Podostemaceæ	20	0	0
Corresponding Societies Committee	15	0	0
	£920	9	11

1902.	£	s.	d.
Electrical Standards	40	0	0
Seismological Observations	35	0	0
Investigation of the Upper Atmosphere by means of Kites	75	0	0
Magnetic Observations at Falmouth	80	0	0
Relation between Absorption Spectra and Organic Substances	20	0	0
Wave-length Tables	5	0	0
Life-zones in British Carboniferous Rocks	10	0	0
Exploration of Irish Caves	45	0	0
Table at the Zoological Station, Naples	100	0	0
Index Generum et Specierum Animalium	100	0	0
Migration of Birds	15	0	0
Structure of Coral Reefs of Indian Ocean	50	0	0
Compound Ascidians of the Clyde Area	25	0	0
Terrestrial Surface Waves	15	0	0
Legislation regulating Women's Labour	30	0	0
Small Screw Gauge	20	0	0
Resistance of Road Vehicles to Traction	50	0	0
Ethnological Survey of Canada	15	0	0
Age of Stone Circles	30	0	0
Exploration in Crete	100	0	0
Anthropometric Investigation of Native Egyptian Soldiers	15	0	0
Excavations on the Roman Site at Gelligaer	5	0	0
Changes in Hæmoglobin	15	0	0
Work of Mammalian Heart under Influence of Drugs	20	0	0
Investigation of the Cyanophyceæ	10	0	0
Reciprocal Influence of Universities and Schools	5	0	0
Conditions of Health essential to carrying on Work in Schools	2	0	0
Corresponding Societies Committee	15	0	0
	£947	0	0

1903.	£	s.	d.
Electrical Standards	35	0	0
Seismological Observations	40	0	0
Investigation of the Upper Atmosphere by means of Kites	75	0	0
Magnetic Observations at Falmouth	40	0	0
Study of Hydro-aromatic Substances	20	0	0
Erratic Blocks	10	0	0
Exploration of Irish Caves	40	0	0
Underground Waters of North-West Yorkshire	40	0	0

	£	s.	d.
Life-zones in British Carboniferous Rocks	5	0	0
Geological Photographs	10	0	0
Table at the Zoological Station at Naples	100	0	0
Index Generum et Specierum Animalium	100	0	0
Tidal Bore, Sea Waves, and Beaches	15	0	0
Scottish National Antarctic Expedition	50	0	0
Legislation affecting Women's Labour	25	0	0
Researches in Crete	100	0	0
Age of Stone Circles	3	13	2
Anthropometric Investigation	5	0	0
Anthropometry of the Todas and other Tribes of Southern India	50	0	0
The State of Solution of Proteids	20	0	0
Investigation of the Cyanophyceæ	25	0	0
Respiration of Plants	12	0	0
Conditions of Health essential for School Instruction	5	0	0
Corresponding Societies Committee	20	0	0
	£845	13	2

1904.

Seismological Observations	40	0	0
Investigation of the Upper Atmosphere by means of Kites	50	0	0
Magnetic Observations at Falmouth	60	0	0
Wave-length Tables of Spectra	10	0	0
Study of Hydro-aromatic Substances	25	0	0
Erratic Blocks	10	0	0
Life-zones in British Carboniferous Rocks	35	0	0
Fauna and Flora of the Trias	10	0	0
Investigation of Fossiliferous Drifts	50	0	0
Table at the Zoological Station, Naples	100	0	0
Index Generum et Specierum Animalium	60	0	0
Development in the Frog	15	0	0
Researches on the Higher Crustacea	15	0	0
British and Foreign Statistics of International Trade	25	0	0
Resistance of Road Vehicles to Traction	90	0	0
Researches in Crete	100	0	0
Researches in Glastonbury Lake Village	25	0	0
Anthropometric Investigation of Egyptian Troops	8	10	0
Excavations on Roman Sites in Britain	25	0	0
The State of Solution of Proteids	20	0	0
Metabolism of Individual Tissues	40	0	0
Botanical Photographs	1	8	11
Respiration of Plants	15	0	0
Experimental Studies in Heredity	35	0	0
Corresponding Societies Committee	20	0	0
	£887	18	11

1905.

Electrical Standards	40	0	0
Seismological Observations	40	0	0
Investigation of the Upper Atmosphere by means of Kites	40	0	0
Magnetic Observations at Falmouth	50	0	0
Wave-length Tables of Spectra	5	0	0
Study of Hydro-aromatic Substances	25	0	0
Dynamic Isomerism	20	0	0
Aromatic Nitroamines	25	0	0
Fauna and Flora of the British Trias	10	0	0
Table at the Zoological Station, Naples	100	0	0
Index Generum et Specierum Animalium	75	0	0
Development of the Frog	10	0	0
Investigations in the Indian Ocean	150	0	0
Trade Statistics	4	4	8
Researches in Crete	75	0	0
Anthropometric Investigations of Egyptian Troops	10	0	0
Excavations on Roman Sites in Britain	10	0	0
Anthropometric Investigations	10	0	0
Age of Stone Circles	30	0	0
The State of Solution of Proteids	20	0	0
Metabolism of Individual Tissues	30	0	0
Ductless Glands	40	0	0
Botanical Photographs	3	17	6
Physiology of Heredity	35	0	0
Structure of Fossil Plants	50	0	0
Corresponding Societies Committee	20	0	0
	£928	2	2

1906.	£	s.	d.
Electrical Standards	25	0	0
Seismological Observations	40	0	0
Magnetic Observations at Falmouth	50	0	0
Magnetic Survey of South Africa	99	12	6
Wave-length Tables of Spectra	5	0	0
Study of Hydro-aromatic Substances	25	0	0
Aromatic Nitroamines	10	0	0
Fauna and Flora of the British Trias	7	8	11
Crystalline Rocks of Anglesey	30	0	0
Table at the Zoological Station, Naples	100	0	0
Index Animalium	75	0	0
Development of the Frog	10	0	0
Higher Crustacea	15	0	0
Freshwater Fishes of South Africa	50	0	0
Rainfall and Lake and River Discharge	10	0	0
Excavations in Crete	100	0	0
Lake Village at Glastonbury	40	0	0
Excavations on Roman Sites in Britain	30	0	0
Anthropometric Investigations in the British Isles	30	0	0
State of Solution of Proteids	20	0	0
Metabolism of Individual Tissues	20	0	0
Effect of Climate upon Health and Disease	20	0	0
Research on South African Cycads	14	19	4
Peat Moss Deposits	25	0	0
Studies suitable for Elementary Schools	5	0	0
Corresponding Societies Committee	25	0	0
	£882	0	9

1907.	£	s.	d.
Electrical Standards	50	0	0
Seismological Observations	40	0	0
Magnetic Observations at Falmouth	40	0	0
Magnetic Survey of South Africa	25	7	6
Wave-length Tables of Spectra	10	0	0
Study of Hydro-aromatic Substances	30	0	0
Dynamic Isomerism	30	0	0
Life Zones in British Carboniferous Rocks	10	0	0
Erratic Blocks	10	0	0
Fauna and Flora of British Trias	10	0	0
Faunal Succession in the Carboniferous Limestone of South-West England	15	0	0
Correlation and Age of South African Strata, &c.	10	0	0
Table at the Zoological Station, Naples	100	0	0
Index Animalium	75	0	0
Development of the Sexual Cells	1	11	8
Oscillations of the Land Level in the Mediterranean Basin	50	0	0
Gold Coinage in Circulation in the United Kingdom	8	19	7
Anthropometric Investigations in the British Isles	10	0	0
Metabolism of Individual Tissues	45	0	0
The Ductless Glands	25	0	0
Effect of Climate upon Health and Disease	55	0	0
Physiology of Heredity	30	0	0
Research on South African Cycads	35	0	0
Botanical Photographs	5	0	0
Structure of Fossil Plants	5	0	0
Marsh Vegetation	15	0	0
Corresponding Societies Committee	16	14	1
	£757	12	10

1908.	£	s.	d.
Seismological Observations	40	0	0
Further Tabulation of Bessel Functions	15	0	0
Investigation of Upper Atmosphere by means of Kites	25	0	0
Meteorological Observations on Ben Nevis	25	0	0
Geodetic Arc in Africa	200	0	0
Wave-length Tables of Spectra	10	0	0
Study of Hydro-aromatic Substances	30	0	0
Dynamic Isomerism	40	0	0
Transformation of Aromatic Nitroamines	30	0	0
Erratic Blocks	17	16	6
Fauna and Flora of British Trias	10	0	0
Faunal Succession in the Carboniferous Limestone in the British Isles	10	0	0
Pre-Devonian Rocks	10	0	0
Exact Significance of Local Terms	5	0	0
Composition of Charnwood Rocks	10	0	0
Table at the Zoological Station at Naples	100	0	0
Index Animalium	75	0	0
Hereditary Experiments	10	0	0
Fauna of Lakes of Central Tasmania	40	0	0
Investigations in the Indian Ocean	50	0	0

	£	s.	d.
Exploration in Spitsbergen ...	30	0	0
Gold Coinage in Circulation in the United Kingdom.....	3	7	6
Electrical Standards	50	0	0
Glastonbury Lake Village ...	30	0	0
Excavations on Roman Sites in Britain	15	0	0
Age of Stone Circles.....	50	0	0
Anthropological Notes and Queries	40	0	0
Metabolism of Individual Tissues.....	40	0	0
The Ductless Glands.....	13	14	8
Effect of Climate upon Health and Disease.....	35	0	0
Body Metabolism in Cancer...	30	0	0
Electrical Phenomena and Metabolism of *Arum Spadices*	10	0	0
Marsh Vegetation	15	0	0
Succession of Plant Remains	18	0	0
Corresponding Societies Committee	25	0	0
	£1,157	18	8

1909.

Seismological Observations...	60	0	0
Investigation of the Upper Atmosphere by means of Kites	10	0	0
Magnetic Observations at Falmouth	50	0	0
Establishing a Solar Observatory in Australia	50	0	0
Wave-length Tables of Spectra	9	16	0
Study of Hydro-aromatic Substances	15	0	0
Dynamic Isomerism.....	35	0	0
Transformation of Aromatic Nitroamines	10	0	0
Electroanalysis	30	0	0
Fauna and Flora of British Trias	8	0	0
Faunal Succession in the Carboniferous Limestone in the British Isles	8	0	0
Palæozoic Rocks of Wales and the West of England	9	0	0
Igneous and Associated Sedimentary Rocks of Glensaul	11	13	9
Investigations at Biskra	50	0	0
Table at the Zoological Station at Naples	100	0	0
Heredity Experiments.....	10	0	0
Feeding Habits of British Birds	5	0	0
Index Animalium.....	75	0	0
Investigations in the Indian Ocean	35	0	0
Gaseous Explosions	75	0	0
Excavations on Roman Sites in Britain	5	0	0
Age of Stone Circles.....	30	0	0
Researches in Crete	70	0	0
The Ductless Glands	35	0	0
Electrical Phenomena and Metabolism of *Arum Spadices*	10	0	0
Reflex Muscular Rhythm.....	10	0	0
Anæsthetics	25	0	0
Mental and Muscular Fatigue	27	0	0
Structure of Fossil Plants ...	5	0	0
Botanical Photographs.....	10	0	0
Experimental Study of Heredity.....	30	0	0
Symbiosis between Turbellarian Worms and Algæ	10	0	0
Survey of Clare Island.....	65	0	0
Curricula of Secondary Schools	5	0	0
Corresponding Societies Committee	21	0	0
	£1,014	9	9

1910.

Measurement of Geodetic Arc in South Africa.....	100	0	0
Republication of Electrical Standards Reports	100	0	0
Seismological Observations...	60	0	0
Magnetic Observations at Falmouth	25	0	0
Investigation of the Upper Atmosphere	25	0	0
Study of Hydro-aromatic Substances	25	0	0
Dynamic Isomerism.....	35	0	0
Transformation of Aromatic Nitroamines	15	0	0
Electroanalysis	10	0	0
Faunal Succession in the Carboniferous Limestone in the British Isles	10	0	0
South African Strata	5	0	0
Fossils of Midland Coalfields	25	0	0
Table at the Zoological Station at Naples	100	0	0
Index Animalium	75	0	0
Heredity Experiments	15	0	0
Feeding Habits of British Birds	5	0	0
Amount and Distribution of Income	15	0	0
Gaseous Explosions	75	0	0
Lake Villages in the Neighbourhood of Glastonbury...	5	0	0
Excavations on Roman Sites in Britain	5	0	0
Neolithic Sites in Northern Greece.....	5	0	0
The Ductless Glands	40	0	0
Body Metabolism in Cancer...	20	0	0
Anæsthetics	25	0	0
Tissue Metabolism	25	0	0
Mental and Muscular Fatigue	18	17	0
Electromotive Phenomena in Plants	10	0	0
Structure of Fossil Plants ...	10	0	0
Experimental Study of Heredity.....	30	0	0

	£	s.	d.
Survey of Clare Island	30	0	0
Corresponding Societies Committee	20	0	0
	£963	17	0

1911.

	£	s.	d.
Seismological Investigations	60	0	0
Magnetic Observations at Falmouth	25	0	0
Investigation of the Upper Atmosphere	25	0	0
International Commission on Physical and Chemical Constants	30	0	0
Study of Hydro-aromatic Substances	20	0	0
Dynamic Isomerism	25	0	0
Transformation of Aromatic Nitroamines	15	0	0
Electroanalysis	15	0	0
Influence of Carbon, &c., on Corrosion of Steel	15	0	0
Crystalline Rocks of Anglesey	2	0	0
Mammalian Fauna in Miocene Deposits, Bugti Hills, Baluchistan	75	0	0
Table at the Zoological Station at Naples	100	0	0
Index Animalium	75	0	0
Feeding Habits of British Birds	5	0	0
Belmullet Whaling Station	30	0	0
Map of Prince Charles Foreland	30	0	0
Gaseous Explosions	90	0	0
Lake Villages in the Neighbourhood of Glastonbury	5	0	0
Age of Stone Circles	30	0	0
Artificial Islands in Highland Lochs	10	0	0
The Ductless Glands	40	0	0
Anæsthetics	20	0	0
Mental and Muscular Fatigue	25	0	0
Electromotive Phenomena in Plants	10	0	0
Dissociation of Oxy-Hæmoglobin	25	0	0
Structure of Fossil Plants	15	0	0
Experimental Study of Heredity	45	0	0
Survey of Clare Island	20	0	0
Registration of Botanical Photographs	10	0	0
Mental and Physical Factors involved in Education	10	0	0
Corresponding Societies Committee	20	0	0
	£922	0	0

1912.[1]

	£	s.	d.
Seismological Investigations	60	0	0
Magnetic Observations at Falmouth	25	0	0
Investigation of the Upper Atmosphere	30	0	0
International Commission on Physical and Chemical Constants	30	0	0
Further Tabulation of Bessel Functions	15	0	0
Study of Hydro-aromatic Substances	20	0	0
Dynamic Isomerism	30	0	0
Transformation of Aromatic Nitroamines	10	0	0
Electroanalysis	10	0	0
Study of Plant Enzymes	30	0	0
Erratic Blocks	5	0	0
Igneous and Associated Rocks of Glensaul, &c.	15	0	0
List of Characteristic Fossils	5	0	0
Sutton Bone Bed	15	0	0
Bembridge Limestone at Creechbarrow Hill	20	0	0
Table at the Zoological Station at Naples	50	0	0
Index Animalium	75	0	0
Belmullet Whaling Station	20	0	0
Secondary Sexual Characters in Birds	10	0	0
Gaseous Explosions	60	0	0
Lake Villages in the neighbourhood of Glastonbury	5	0	0
Artificial Islands in Highland Lochs	10	0	0
Physical Character of Ancient Egyptians	40	0	0
Excavation in Easter Island	15	0	0
The Ductless Glands	35	0	0
Calorimetric Observations on Man	40	0	0
Structure of Fossil Plants	15	0	0
Experimental Study of Heredity	35	0	0
Survey of Clare Island	20	0	0
Jurassic Flora of Yorkshire	15	0	0
Overlapping between Secondary and Higher Education	1	18	6
Curricula, &c., of Industrial and Poor Law Schools	10	0	0
Influence of School Books upon Eyesight	3	9	0
Corresponding Societies Committee	25	0	0
Collections illustrating Natural History of Isle of Wight	40	0	0
	£845	7	6

[1] For grants from Caird Fund in this and following years, see p. lxxii.

1913.	£	s.	d.
Seismological Investigations	60	0	0
Investigation of the Upper Atmosphere	50	0	0
International Commission on Physical and Chemical Constants	40	0	0
Further Tabulation of Bessel Functions	30	0	0
Study of Hydro-aromatic Substances	20	0	0
Dynamic Isomerism	30	0	0
Transformation of Aromatic Nitroamines	20	0	0
Study of Plant Enzymes	30	0	0
Igneous and Associated Rocks of Glensaul, &c	10	0	0
List of Characteristic Fossils	5	0	0
Exploration of the Upper Old Red Sandstone of Dura Den	75	0	0
Geology of Ramsey Island	10	0	0
Old Red Sandstone Rocks of Kiltorcan	15	0	0
Table at the Zoological Station at Naples	50	0	0
Ditto (Special Grant)	50	0	0
Nomenclator Animalium Generum et Sub-generum	100	0	0
Belmullet Whaling Station	15	0	0
Ditto (Special Grant)	10	0	0
Gaseous Explosions	80	0	0
Lake Villages in the Neighbourhood of Glastonbury	5	0	0
Age of Stone Circles (Special Grant)	15	0	0
Artificial Islands in the Highlands of Scotland	5	0	0
Excavations on Roman Sites in Britain	15	0	0
Hausa Manuscripts	20	0	0
The Ductless Glands	40	0	0
Calorimetric Observations on Man	45	0	0
Dissociation of Oxy-Hæmoglobin at High Altitudes	15	0	0
Structure and Function of the Mammalian Heart	20	0	0
Structure of Fossil Plants	15	0	0
Jurassic Flora of Yorkshire	4	12	4
Vegetation of Ditcham Park, Hampshire	45	0	0
Influence of School Books on Eyesight	9	4	9
Corresponding Societies Committee	25	0	0
	£978	17	1

1914.			
Seismological Investigations	130	0	0
Investigation of the Upper Atmosphere	25	0	0
International Commission on Physical and Chemical Constants	40	0	0
Calculation of Mathematical Tables	20	0	0
Disposal of Copies of the 'Binary Canon'	4	9	0
Study of Hydro-aromatic Substances	15	0	0
Dynamic Isomerism	25	0	0
Transformation of Aromatic Nitroamines	15	0	0
Study of Plant Enzymes	25	0	0
Correlation of Crystalline Form with Molecular Structure	25	0	0
Study of Solubility Phenomena	10	0	0
List of Characteristic Fossils	5	0	0
Geology of Ramsey Island	10	0	0
Fauna and Flora of Trias of Western Midlands	10	0	0
Critical Sections in Lower Palæozoic Rocks	15	0	0
Belmullet Whaling Station	20	0	0
Nomenclator Animalium Generum et Sub-generum	50	0	0
Antarctic Whaling Industry	75	0	0
Maps for School and University Use	40	0	0
Gaseous Explosions	50	0	0
Stress Distributions in Engineering Materials	50	0	0
Lake Villages in the Neighbourhood of Glastonbury	20	0	0
Age of Stone Circles	20	0	0
Artificial Islands in the Highlands of Scotland	5	0	0
Excavations on Roman Sites in Britain	20	0	0
Anthropometric Investigations in Cyprus	50	0	0
Palæolithic Site in Jersey	50	0	0
The Ductless Glands	35	0	0
Calorimetric Observations on Man	40	0	0
Structure and Function of the Mammalian Heart	30	0	0
Binocular Combination of Kinematograph Pictures	0	17	0
Structure of Fossil Plants	15	0	0
Jurassic Flora of Yorkshire	5	0	0
Flora of the Peat of the Kennet Valley	15	0	0
Vegetation of Ditcham Park	14	4	3
Physiology of Heredity	30	0	0
Breeding Experiments with Œnotheras	19	17	4
Mental and Physical Factors involved in Education	20	0	0
Influence of School Books on Eyesight	2	8	9

	£	s.	d.
Character, Work, and Maintenance of Museums	10	0	0
Corresponding Societies Committee	25	0	0
	£1,086	16	4

1915.

	£	s.	d.
Seismological Observations	130	0	0
Annual Table of Constants, &c.	40	0	0
Calculation of Mathematical Tables	25	0	0
Dynamic Isomerism	40	0	0
Transformation of Aromatic Nitroamines	20	0	0
Study of Plant Enzymes	10	0	0
Chemical Investigation of Natural Plant Products	50	0	0
Influence of Weather Conditions on Nitrogen Acids in Rainfall	40	0	0
Non-Aromatic Diazonium Salts	5	0	0
Biology of Abrolhos Islands	40	0	0
Collection of Marsupials	100	0	0
Survey of Stor Fjord, Spitsbergen	50	0	0
Antarctic Bathymetrical Chart	100	0	0
Fatigue from Economic Standpoint	30	0	0
Gaseous Explosions	50	0	0
Stress Distributions	50	0	0
Lake Villages in the Neighbourhood of Glastonbury	20	0	0
Age of Stone Circles	10	0	0
Palæolithic Site in Jersey	50	0	0
Excavations in Malta	10	0	0
Gazetteer and Map of Native Tribes in Australia	20	0	0
Electromotive Phenomena of the Heart	20	0	0
Metabolism of Phosphates	20	0	0
Structure of Fossil Plants	6	0	0
Physiology of Heredity	45	0	0
Renting of Cinchona Botanic Station, Jamaica	25	0	0
Influence of Percentages of Oxygen	50	0	0
Australian Cycadaceæ	25	0	0
Sections of Australian Fossil Plants	25	0	0
Influence of School Books on Eyesight	5	0	0
Scholarships, &c., held by University Students	3	2	8
Character, Work, and Maintenance of Museums	20	0	0
Corresponding Societies Committee	25	0	0
	£1,159	2	8

1916.

	£	s.	d.
Seismological Investigations	130	0	0
Tables of Constants	40	0	0
Mathematical Tables	35	0	0
Dynamic Isomerism	20	0	0
Non-Aromatic Diazonium Salts	8	10	0
Old Red Sandstone Rock of Kiltorcan	7	0	0
Old Red Sandstone Rock of Rhynie	25	0	0
Belmullet Whaling Station	25	0	0
Fatigue from Economic Standpoint	20	0	0
Industrial Unrest	20	0	0
Women in Industry	90	0	0
Effect of War on Credit	25	0	0
Stress Distributions	40	0	0
Engineering Problems affecting the Prosperity of the Country	10	0	0
Physical Characters of Ancient Egyptians	12	8	1
Palæolithic Site in Jersey	25	0	0
Distribution of Bronze Age Implements	3	5	9
Ductless Glands (1914)	35	0	0
„ „ (1915)	14	0	0
Physiology of Heredity	45	0	0
Renting of Cinchona Station	12	10	0
Mental and Physical Factors involved in Education	20	0	0
School Books and Eyesight	3	5	0
Museums	15	0	0
Free Place System	10	0	0
Corresponding Societies Committee	25	0	0
	£715	18	10

1917.

	£	s.	d.
Seismological Observations	100	0	0
Tables of Constants	40	0	0
Mathematical Tables	20	0	0
Dynamic Isomerism	15	0	0
Absorption Spectra, &c.	10	0	0
Old Red Sandstone Rocks of Kiltorcan	4	0	0
Fatigue from Economic Standpoint	40	0	0
Physical Character of Ancient Egyptians	2	11	11
Palæolithic Site in Jersey	25	0	0
Archæological Investigation in Malta	20	0	0
Distribution of Bronze Age Implements	1	14	3
Artificial Islands in Highland Lochs	2	10	0
Ductless Glands	6	0	0
Psychological War Research	10	0	0
Physiology of Heredity	45	0	0

	£	s.	d.
Ecology of Fungi	8	0	0
Mental and Physical Factors involved in Education	10	0	0
Museums	15	0	0
School Books and Eyesight	5	0	0
Free Place System	15	0	0
Science Teaching in Secondary Schools	8	1	0
Corresponding Societies Committee	25	0	0
	£427	17	2

1918.

	£	s.	d.
Seismological Observations	100	0	0
Colloid Chemistry and its Industrial Applications	10	0	0
Old Red Sandstone Rocks of Kiltorcan	5	0	0
Inheritance in Silkworms	3	0	0
Women in Industry	10	0	0
„ „ (1917)	10	0	11
Effects of the War on Credit etc.	10	0	0
„ „ „ (1917)	10	0	0
Archæological Investigation in Malta	10	0	0
Distribution of Bronze Age Implements	0	18	6
Artificial Islands in Highland Lochs	2	10	0
Physiology of Heredity	15	0	0
Free Place System	5	0	0
Science Teaching in Secondary Schools	4	3	10
Corresponding Societies Committee	25	0	0
	£220	13	3

GENERAL MEETINGS AT BOURNEMOUTH.

On Tuesday, September 9, at 8.30 P.M., in the Winter Gardens Pavilion, Sir Arthur Evans, F.R.S., resigned the office of President to the Hon. Sir Charles Parsons, K.C.B., F.R.S. Before vacating the chair, Sir Arthur Evans moved, and it was unanimously resolved, that the following message be forwarded to His Majesty the King:—

YOUR MAJESTY,—

On the occasion of the outbreak of the great war we, the Members of the British Association for the Advancement of Science, at that time assembled in our eighty-fifth Congress, gave an unanimous expression to our devoted loyalty to Your Majesty's person, which Your Majesty was graciously pleased to acknowledge.

To-day, once more assembled in our eighty-seventh Congress, it is our heart-felt desire on the victorious conclusion of the war and the formal proclamation of peace, to renew those assurances and to express, in more than a formal manner, our high sense of the example of self-sacrificing devotion to the service of the country that has been so simply offered by Your Majesty throughout this long and arduous struggle.

We are painfully aware indeed that, in spite of the decision in the field, the period of stress is by no means over. We cannot from our special point of view be blind to the extent to which the bitter emergencies of war-time have been prejudicial to those ideas and methods which it is our mission to promote. But in the not less arduous struggle that lies before us to regain the stable paths of peace we are heartened by the knowledge that the same wise and conciliating influence and high example that was of such sovran help to the British people in war-time will still be with them.

His Majesty was graciously pleased to accept the above Address.

Sir Arthur Evans referred to eminent members of the Association who had died since the previous meeting. These included the following:—

The Right Hon. Lord Rayleigh, F.R.S., President, 1884; Trustee-1883-1919.

Sir William Crookes, F.R.S., President, 1898.

Professor G. Carey Foster, F.R.S., General Treasurer, 1898-1904; Trustee, 1916-19.

Dr. A. G. Vernon Harcourt F.R.S., General Secretary, 1883-1897

Sir Charles Parsons then delivered an Address, for which see page 3.

On Wednesday evening, September 10, at 8 P.M., a conversazione was given in the Winter Gardens Pavilion by His Worship the Mayor of Bournemouth.

On Thursday, September 11, at 8.30 P.M., in the Winter Gardens Pavilion, Sir Arthur Evans, F.R.S., delivered a discourse on 'The Palace of Minos and the Prehistoric Civilisation of Crete.' (See p. 416.)

On Friday, September 12, at 8.30 P.M., in the Winter Gardens Pavilion, Mr. Sidney G. Brown, F.R.S., delivered a discourse on 'The Gyroscopic Compass.' (See p. 418.)

After the above discourse (the occasion being the concluding General Meeting), the following resolution was unanimously adopted on the motion of the President:—

That the cordial thanks of the British Association be extended to the Mayor, Corporation, and Citizens of the Borough of Bournemouth (especially to the

members of Bournemouth Natural History Society) for their hearty welcome, to the Corporation in particular for placing their magnificent Municipal College and the Winter Gardens Pavilion at the disposal of the Association; to the Municipal and other Authorities, particularly those of H.M. Cordite Factory, Holton Heath, who have authorised facilities for excursions of high scientific interest; and finally to the Local Officers and their able assistants, and to the Local Executive Committee and individual members thereof for the admirable arrangements made for the meeting.

OFFICERS OF SECTIONS AT THE BOURNEMOUTH MEETING, 1919.

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCE.

President.—Prof. A. Gray, M.A., LL.D., F.R.S. *Vice-Presidents.*—Col. Sir Charles Close, K.B.E., C.B., F.R.S., Sir Oliver Lodge, D.Sc., LL.D., F.R.S., Prof. A. N. Whitehead, Sc.D., F.R.S. *Secretaries.*—W. Makower, M.A., D.Sc. (Recorder); H. R. Hassé; J. Jackson; A. O. Rankine, D.Sc.; E. Fenwick, M.A., LL.D., B.Sc.

SECTION B.—CHEMISTRY.

President.—Prof. P. Phillips Bedson, D.Sc. *Vice-Presidents.*—Prof. E. C. C. Baly, C.B.E., M.Sc., F.R.S.; Prof. G. G. Henderson, M.A., D.Sc., LL.D., F.R.S., F.I.C. *Secretaries.*—A. Holt, M.A., D.Sc. (Recorder); Prof. C. H. Desch, D.Sc., Ph.D.; Prof. R. Robinson, D.Sc.; H. Painter, B.Sc., F.C.S.

SECTION C.—GEOLOGY.

President.—J. W. Evans, D.Sc., LL.B., F.G.S. *Vice-Presidents.*—Prof. W. S. Boulton, D.Sc., F.G.S.; Sir W. Boyd Dawkins, D.Sc., F.R.S.; Dr. W. G. Miller; Prof. S. H. Reynolds, M.A., Sc.D.; Prof. W. J. Sollas, Sc.D., F.R.S.; Sir A. Strahan, K.B.E., F.R.S. *Secretaries.*—W. T. Gordon, D.Sc. (Recorder); Prof. A. R. Dwerryhouse, D.Sc.; G. Hickling, D.Sc.; W. T. Ord, L.R.C.P. Lond., M.R.C.S.

SECTION D.—ZOOLOGY.

President.—F. A. Dixey, M.A., M.D., F.R.S. *Vice-Presidents.*—E. J. Allen, D.Sc., F.R.S.; Prof. E. W. MacBride, D.Sc., F.R.S.; Lt.-Col. H. W. Marett Tims, O.B.E., M.D. *Secretaries.*—Prof. J. H. Ashworth, D.Sc., F.R.S. (Recorder); F. Balfour Browne, M.A.; R. Douglas Laurie, M.A.; F. G. Penrose, M.D., M.R.C.P., F.Z.S., M.B.O.U.

SECTION E.—GEOGRAPHY.

President.—Prof. L. W. Lyde, M.A. *Vice-Presidents.*—G. G. Chisholm, M.A., B.Sc.; Prof. H. J. Fleure, D.Sc.; Col. Sir T. H. Holdich, K.C.M.G., K.C.I.E., C.B.; Miss M. I. Newbigin, D.Sc.; E. A. Reeves, F.R.G.S. *Secretaries.*—J. McFarlane, M.A. (Recorder); C. B. Fawcett; J. Scattergood.

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

President.—Sir Hugh Bell, Bart., D.L., J.P. *Vice-Presidents.*—Prof. A. W. Kirkaldy, M.A., M.Com.; Prof. W. R. Scott, M.A., Litt.D. *Secretaries.*—C. R. Fay, M.A. (Recorder); A. W. Ashby; J. Cunnison; F. H. Pilcher.

SECTION G.—ENGINEERING.

President.—Prof. J. E. Petavel, D.Sc., F.R.S. *Vice-Presidents.*—Prof. W. E. Dalby, M.A., B.Sc., F.R.S.; Sir A. Ewing, F.R.S.; Sir E. Tennyson d'Eyncourt, K.C.B.; Sir R. Hadfield, Bart., D.Sc., F.R.S.; Prof. G. G. Stoney, F.R.S. *Secretaries.*—Prof. G. W. O. Howe, D.Sc. (Recorder); Prof. W. H. Watkinson; I. Bulfin, B.A., A.M.I.C.E., M.I.M.E., M.I.E.E.

SECTION H.—ANTHROPOLOGY.

President.—Prof. A. Keith, M.A., LL.D., F.R.S. *Vice-Presidents.*—W. Crooke, B.A.; R. R. Marett, D.Sc.; Prof. J. L. Myres, M.A. F.S.A. *Secretaries.*—F. C. Shrubsall, M.A., M.D. (Recorder); E. N. Fallaize, B.A.; Rev. E. O. James; Claude Lyon.

SECTION I.—PHYSIOLOGY.

President.—Prof. D. Noël Paton, M.D., F.R.S. *Vice-Presidents.*—Prof. W. M. Bayliss, D.Sc., F.R.S.; Prof. A. R. Cushny, M.D., F.R.S.; Prof. W. D. Halliburton, M.D., F.R.S.; C. S. Myers, M.D., Sc.D., F.R.S.; Prof. W. H. R. Rivers, M.D., F.R.S.; Prof. E. H. Starling, M.D. *Secretaries*—H. E. Roaf, M.D., D.Sc. (Recorder); C. L. Burt; A. C. Coles, M.D., D.Sc.; C. Lovatt Evans, D.Sc.

SECTION K.—BOTANY.

President.—Sir Daniel Morris, K.C.M.G., M.A., D.Sc., D.C.L., LL.D. *Vice-Presidents.*—Rev. Prof. Henslow; Prof. M. C. Potter, M.A.: A. B. Rendle, M.A., F.R.S.; Miss E. R. Saunders, F.L.S.; D. H. Scott, LL.D., D.Sc., F.R.S.; H. W. T. Wager, F.R.S. *Secretaries.*—Miss E. N. Thomas, D.Sc. (Recorder); F. T. Brooks; W. E. Hiley; W. Munn Rankin, M.Sc., B.Sc.

SECTION L.—EDUCATIONAL SCIENCE.

President.—Sir Napier Shaw, M.A., Sc.D., F.R.S. *Vice-Presidents.*—Prof. H. E. Armstrong, Ph.D., LL.D., F.R.S.; Sir R. Blair, M.A., B.Sc.; Prof. J. A. Green, M.A.; Sir R. A. Gregory; E. H. Griffiths, M.A., D.Sc., F.R.S.; Rev. Canon W. Temple, M.A. *Secretaries.*—D. Berridge, M.A. (Recorder); C. E. Browne, B.Sc.; E. H. Tripp, Ph.D.; C. J. Whitting.

SECTION M.—AGRICULTURE.

President.—Prof. W. Somerville, D.Sc. *Vice-Presidents.*—Principal P. H. Foulkes; F. W. Keeble, C.B.E., Sc.D., F.R.S.; E. J. Russell, O.B.E., D.Sc., F.R.S.; Rt. Hon. Viscount Wimborne. *Secretaries.*—A. Lauder, D.Sc. (Recorder); C. G. T. Morrison; T. J. Meaby, F.S.I.

CONFERENCE OF DELEGATES OF CORRESPONDING SOCIETIES.

President.—The Right Hon. Lord Montagu of Beaulieu, C.C., J.P., V.D., D.L. *Vice-President.*—W. Dale, F.S.A. *Secretary.*—W. Mark Webb.

REPORT OF THE COUNCIL, 1918-19.

I. The Council have to record with deep regret the death of Lord Rayleigh, O.M., F.R.S. (President, 1884; Trustee, 1883-1919), of Sir William Crookes, O.M., F.R.S. (President, 1898), of George Carey Foster, LL.D., D.Sc., F.R.S. (General Treasurer, 1898-1904; Trustee, 1916-19); and of Augustus George Vernon Harcourt, M.A., D.C.L., LL.D., D.Sc., F.R.S. (General Secretary, 1883-97).

II. Professor W. A. Herdman, F.R.S., has been unanimously nominated by the Council to fill the office of President of the Association for the year 1920-21 (Cardiff Meeting).

III. Resolutions referred by the General Committee, July 5, 1918, to the Council for consideration, and, if desirable, for action, were dealt with as follows:—

From the General Committee.

'That, having regard to the expression of opinion here and elsewhere, the Council be respectfully requested to consider the question of holding a Meeting of the Association in or near London during the year 1919, if the Bournemouth Meeting be dropped.'

On consideration of this resolution, the Council appointed the following Committee (with power to add to their number):—

The President and General Officers, the President-elect, Sir E. Brabrook, Sir Dugald Clerk, Sir R. A. Gregory, Sir E. im Thurn, Major P. A. MacMahon,

with the following terms of reference:

'To consider and report upon the question whether, in the event of it being impossible to hold an ordinary Annual Meeting in 1919 in Bournemouth or elsewhere, a Meeting of the Association in London is desirable, and, if so, to suggest arrangements for such a Meeting.'

It was fortunately, however, unnecessary for the above Committee to meet, as the invitation from Bournemouth was cordially renewed and unanimously accepted, the Council expressing thanks on behalf of the Association to the municipality of Bournemouth for the renewed invitation.

From Section H.

'The Organising Committee of Section H submit to the Committee of Recommendations that they should recommend the Council of the Association to send a communication on behalf of the Association to the University of New Zealand, Wellington, stating that "the British Association for the Advancement of Science expresses its strong approval of the movement for promoting the teaching of anthropology by the University of New Zealand."'

The Council resolved that such a communication should be forwarded.

IV. The General Officers reported to the Council that they had received from the Assistant Secretary a memorandum dealing with the future cost and distribution of the Annual Volume, with membership fees and rights, and with certain arrangements at Annual Meetings, and that they considered these matters worthy of consideration by the Council.

The Council appointed the following Committee (with power to add to their number):—

The President and General Officers, the President-elect, Mr. D. Berridge, Sir E. Brabrook, Sir Dugald Clerk, Sir R. A. Gregory, Dr. E. H. Griffiths, Prof. S. J. Hickson, Dr. A. Holt, Dr. Ethel Thomas,

with the following terms of reference:—

'To review and report upon the working of the Association, with especial reference to the future cost and distribution of the Annual Volume, membership fees and rights, arrangements at the Annual Meeting, and other matters germane to the receipts and expenditure of the Association.'

The Committee duly reported, and the Council, having adopted the report with one amendment, transmit it to the General Committee as a separate addendum to the present report.

V. On the proposal of the South African Association for the Advancement of Science, it was resolved that the trustees of the South African Medal Fund should in future be designated as follows (in amendment of resolution under *Minute* of Council, Nov. 1906, §3):—

The Superintendent-General of Education for the Cape Province, the Controller and Auditor-General for the Union of South Africa, the Registrar of the University of South Africa.

VI. The Royal Society made a grant to the Association of £100 for physical research and £150 for purposes of publication. The grateful thanks of the Council were conveyed to the Society.

VII. The Department of Scientific and Industrial Research were asked, and consented, to recommend the publication of the Second

Report on Colloid Chemistry by H.M. Stationery Office, and this has been done in the name of the Association, the Stationery Office acquiring the copyright, and the Association receiving 2,000 copies of the report for incorporation with the Annual Volume, at the cost price of £70.

VIII. Caird Fund.—The Council made the following grant during the year, additional to annual grants previously made:—

Conjoint Board of Scientific Societies £10

IX. Conference of Delegates and Corresponding Societies Committee:—

The following Nominations are made by the Council:—

Conference of Delegates.—Lord Montagu of Beaulieu (*President*), Mr. W. Dale (*Vice-President*), Mr. W. Mark Webb (*Secretary*).

Corresponding Societies Committee.—Mr. W. Whitaker (*Chairman*), Mr. W. Mark Webb (*Secretary*), Rev. J. O. Bevan, Sir Edward Brabrook, Sir H. G. Fordham, Mr. A. L. Lewis, Rev. T. R. R. Stebbing, Mr. Mark L. Sykes, and the President and General Officers of the Association.

X. The Council have received reports from the General Treasurer during the past year. His accounts have been audited and are presented to the General Committee.

XI. The retiring members of the Council are:—

By seniority.—Sir E. Brabrook, Prof. W. D. Halliburton.
By least attendance.—Prof. H. N. Dickson, Sir E. Rutherford, Prof. F. E. Weiss.

The Council nominated the following members:—

Prof. A. Fowler,
Prof. A. W. Kirkaldy,
Prof. J. L. Myres,

leaving two vacancies to be filled by the General Committee without nomination by the Council.

The full list of nominations of ordinary members is as follows:—

Dr. E. F. Armstrong.
Prof. W. A. Bone.
Sir Dugald Clerk.
Prof. A. Dendy.
Dr. F. A. Dixey.
Sir F. W. Dyson.
Prof. A. Fowler.
Sir R. A. Gregory.
Dr. S. F. Harmer.
Sir Everard im Thurn.
Prof. J. H. Jeans.
Prof. A. Keith.
Prof. A. W. Kirkaldy.
Sir Daniel Morris.
Prof. J. L. Myres.
Prof. W. H. Perkin.
Dr. E. J. Russell.
Miss E. R. Saunders.
Prof. W. R. Scott.
Prof. E. H. Starling.
Sir A. Strahan.
Mr. W. Whitaker.
Dr. A. Smith Woodward.

XII. The General Officers have been nominated by the Council as follows:—

General Treasurer: Prof. J. Perry.
General Secretary: Prof. H. H. Turner.

The Council received, with great regret, Prof. W. A. Herdman's resignation of the office of General Secretary, which he had held since 1903.

The Council appointed a committee, consisting of the President and General Officers, the President-elect, Sir J. J. Thomson, Dr. T. G. Bonney, Sir E. Sharpey Schäfer, Sir Oliver Lodge, Prof. W. Bateson, Prof. A. Schuster, Dr. A. Vernon Harcourt, Dr. D. H. Scott, Major P. A. MacMahon, and Sir E. Brabrook, to select a name or names for the consideration of the Council when nominating Prof. Herdman's successor.

On the report of this Committee, the Council have made the following nomination:—

General Secretary: Prof. J. L. Myres.

XIII. The following have been admitted as members of the General Committee:—

Dr. E. N. da C. Andrade.
Prof. P. G. H. Boswell.
Prof. L. Doncaster.
Prof. A. Fowler.
Sir R. Hadfield.
Prof. H. H. Hilton.
Prof. W. C. McC. Lewis.
Prof. F. A. Lindemann.
Dr. A. Low.
Miss T. L. Prankerd.
Lady Shaw.
Sir R. F. Stupart.
Dr. C. Tierney.

THE WORKING OF THE ASSOCIATION.

REPORT BY THE COUNCIL TO THE GENERAL COMMITTEE, 1919.

Introduction.

The Council, having received a report from the General Officers in 1918, appointed a Committee consisting of the President and General Officers, the President-elect, Mr. D. Berridge, Sir Edward Brabrook, Sir Dugald Clerk, Sir R. A. Gregory, Dr. E. H. Griffiths, Prof. S. J. Hickson, Dr. A. Holt, and Dr. Ethel Thomas,

> 'To consider and report upon the working of the Association, with especial reference to the future cost and distribution of the Annual Volume, membership fees and rights, arrangements at the Annual Meetings, and other matters germane to the receipts and expenditure of the Association.'

The Council also referred to the Committee a suggestion received from Mr. R. T. A. Innes (Union Astronomer, Johannesburg Observatory) that a system of 'institutional membership' should be adopted, whereby institutions should be enabled to subscribe to the Association, send representatives, and receive the Annual Report.

In the first instance each member of the Committee received a copy of a memorandum prepared by the Assistant Secretary, and was asked to comment upon it in writing, and at the same time to bring forward any matters, not covered by the memorandum, which it might seem desirable for the Committee to discuss. A digest of the views expressed by members in response to this request was drawn up and circulated, and the Committee discussed the various questions thus raised at a meeting on March 7, 1919. The Committee's report was afterwards drawn up, and was presented to the Council on June 6, 1919, and their recommendations, with one exception, were adopted by the Council (see next page), and ordered to be forwarded to the General Committee.

Subjects Considered and Recommendations.

(*A*) *Membership Subscriptions, Rights of Members, and Distribution of the Annual Volume.*

In dealing with these the Committee had before them the following principal considerations:

(*a*) That the cost of printing, and therefore the cost of the Annual Volume of the Association, had considerably increased in recent years before the war, and has done so very largely during the war.

(*b*) That under the present system whereby Life Members, New Annual Members, Old Annual Members subscribing regularly, and Honorary Corresponding Members, are entitled to the Annual Volume free, a not inconsiderable number receive the volume who do not really require it.

(*c*) That an excessive number of libraries and institutions receive the volume free, and that any publications received by the Association in exchange are not of commensurate value.

(*d*) That in view of the above conditions the cost of the Annual Volume has become an excessive charge upon the funds of the Association.

(*e*) That the division between Members and Associates (of whom the latter have no right to hold office, serve on committees, or receive the volume free) gives rise to frequent difficulty, as when it is desired to appoint to office or on a committee a person who has joined only as an Associate, and it becomes necessary to demand from him a further subscription of £1 so that he may become a 'new annual member.'

(*f*) That the present subscription for life membership (£10, with right to receive the Annual Volume free) is too low.

With these and other considerations in mind, the Committee reviewed the whole question of subscriptions and the distribution of the Annual Volume, and after consideration of their report, the Council make the following recommendations:

(1) **New Life Membership Fee, £15, including right to receive the Annual Volume free.**—Under present arrangements, Life Members are asked each year whether they wish to claim the Annual Volume: they should be invited to refrain from doing so unless they have a real use for it.

The Council recognise that the **position of present Life Members must remain unaffected.** But they recommend that the General Treasurer be instructed to lay before present Life Members the position in respect of the increase in the cost of the Annual Volume (and of the administration of the Association in other directions), and to invite them, if they wish to continue to receive the volume, to add a sum not exceeding £5 to their previous subscription.

(It should be added that the Committee had before them proposals on equitable grounds for a sliding scale of life-member-

ship fees according to age, but after consideration they preferred to recommend the continuance of the usual arrangement of a flat rate.)

(2) **Scale of Fees for New Annual Members**—

(*a*) Subscription payable before the close of the Annual Meeting, including right to attend the Meeting and to receive the Annual Volume—**£1 10s.**

(*b*) Subscription for the Annual Meeting but excluding right to receive the Annual Volume—**£1.**

(*c*) Subscription of members not attending the Annual Meeting, but desiring to receive the Annual Volume —**£1.**

(Any of the above subscriptions to carry the present eligibility to service as officers or on committees.)

The Council recognise that the right of old annual members subscribing regularly to receive the Annual Volume free (if they wish it) must remain unaffected.

(3) **Abolition of present 'entrance fee' of £1 for new annual members.**

(4) **Abolition of Associateship.**—All persons joining the Association would thus have the same rights and privileges in respect of eligibility to office or committee-service; the Council believe that by this means a not uncommon source of friction would be removed; moreover, a measure of simplification in the issue of tickets, accounting, etc., would be introduced.

(5) **Transferable Tickets, £1 5s.**—These should not be confined to Ladies, as at present. They should carry no right to the Annual Volume.

(6) **'Students' Tickets,' 10s.**—These, confined to university and other students, teachers, etc., vouched for by the Local Executive as resident or working in the locality where the Annual Meeting takes place, have already been experimentally introduced with success, and should be established on a regular footing.

(7) All Annual Members who, having attended the Annual Meeting, have *not* paid the subscription entitling them to the Annual Volume, should be advised, shortly before the volume is ready for issue, that they may obtain it by payment of **12s. 6d.** within a fixed period, not extending beyond the close of the financial year (June 30).

(8) **Publication price of the Annual Volume, £1 5s.**

(9) **Honorary Corresponding Members** should be entitled to the Annual Volume free upon application each year.

(10) **Libraries and Institutions** should be entitled to purchase the Annual Volume at a subscription rate of **12s. 6d.** per annum, and libraries and institutions which at present receive the Volume free should be informed accordingly, subject to any statutory rights or other considerations.

(11) The Council do *not* recommend the adoption of '**Institutional Membership.**'

(12) **Membership Tickets for Subscribers to Local Funds.**—When a guarantee or subscription fund is to be raised, to meet local expenses of an Annual Meeting, in the locality where the meeting is to be held, there should be a regular understanding that £1 from each guarantee or subscription of £5 or over should be paid by the Local Executive to the Association, in return for which the Association will provide each guarantor of £5 or over with a ticket of membership for the meeting.

(B) *Changes in the Annual Volume, and Separate Issue of Sectional Transactions.*

Questions of possible changes in the contents of the Annual Volume, and the partial substitution of an issue of separate transactions of individual Sections, were reopened before the Committee, but they considered that the discussion of these questions in recent years (culminating in a plébiscite of members) has disposed of them.

The Committee considered, however, that if any Sectional Committee in any year is aware of a demand for not less than 50 copies of a separate issue of its transactions, and will undertake their distribution by sale so as to repay the extra cost of these copies, the Council should sanction such separate sale. The Council accepts this recommendation.

(C) *Arrangements at Annual Meetings.*

(1) **Duration of Annual Meeting.**—There is support for the permanent adoption of the period Tuesday—Saturday for the Annual Meeting (as at the recent Manchester and Newcastle meetings), and there are strong arguments in its favour as against the old period, Wednesday—Wednesday. But the period Tuesday—Saturday has been decided upon for the meeting this year at Bournemouth, and the Council consider that this will afford further opportunity for consideration of the question; they therefore make no recommendation.

(2) **Numbering of Seats at Inaugural Meetings and Evening Discourses.**—It has been proposed that this practice should be given up, in order to simplify work at the Reception Room counters, and to avoid penalising members who cannot arrive, and book seats, early. On this proposal all seating (except any retained for officers, members of General Committee, or guests) would be unreserved, and the membership ticket alone would admit.

The Committee made no recommendation, but they suggested that the General Officers, with the Assistant Secretary, at the forthcoming meeting, be instructed to inquire into the question on the spot, and this suggestion will be carried out.

(3) **Excursions.**—An opinion has long existed that the general excursions which used to be arranged for Members attending

Annual Meetings had little or no connection with the scientific work of the Association, and had besides other obvious disadvantages.

The Council consider that the question whether general excursions be arranged, and their arrangement, if decided upon, ought to be left entirely to the Local Executive: that the Association should not ask for them as part of the regular programme, and that the permanent officials of the Association should undertake no duties in connection with them.

The Council consider that sectional excursions for the purpose of field-work, visits to works, etc., arranged by Organising Sectional Committees, are appropriate to the work of the Association and should be encouraged.

(4) **Attendance of non-Members as Speakers at Sectional Meetings.**—The Council recognise that on occasion a discussion in a Section may be enhanced in value by the presence of specially qualified speakers, who may not be Members of the Association, invited by the Organising Committee. But they consider that Organising Committees should exercise discretion as to the number of speakers so invited, and (while not proposing a fixed limit to the number of such invitations) they recommend that it be a direction to Organising Committees that their Recorders shall acquaint the Assistant Secretary with the names of non-members proposed as speakers, in order that he may inform such persons of the terms and privileges of membership or (at the General Treasurer's discretion) issue ' special admission ' tickets to them for any particular sectional meeting.

(5) **Service of non-Members on Research Committees.**—The Council recognise that the expert assistance of non-members may, on occasion, be essential to the success of a Research Committee's work. They recommend that the names of such persons should appear in a separate category as assessors or consultative or co-opted members of the Committee.

(D) *Grants.*

The Committee received a suggestion that in view of the increase of other claims upon the revenue of the Association, the funds devoted to purposes connected with research should be more closely limited to incidental expenses, inasmuch as other funds have become available to assist research itself. While recognising the extreme importance of this question, the Committee did not discuss it at length, understanding that another opportunity might arise for the Council to consider it.

The Council will make a separate report to the General Committee on this question.

(NOTE.—The recommendations in the above report were adopted by the General Committee, which ordered that alterations in the Rules, where necessary to give effect to changes proposed, should be made.)

Dr. **THE GENERAL TREASURER IN ACCOUNT WITH THE ADVANCEMENT OF SCIENCE,**

RECEIPTS.

	£ s. d.	£ s. d.	£ s. d.
To Balance brought forward :—			
Lloyds Bank, Birmingham		1,877 6 11	
Bank of England—Western Branch :—			
On 'Caird Fund'	493 10 4		
Less General Account overdrawn	68 4 10		
		425 5 6	
		2,302 12 5	
Cash in hand	1 1 11		
Less Petty Cash overdrawn	0 13 1		
		0 8 10	
			2,303 1 3
Life Compositions (including Transfers)			153 0 0
Annual Subscriptions			345 0 0
New Annual Members' Subscriptions			20 0 0
Sale of Publications			182 12 3
Grants from Royal Society:—			
In aid of Publication Expenses		150 0 0	
For purposes of Research		100 0 0	
			250 0 0
Donations			35 0 0
Income Tax Recovered			443 18 2
Interest on Deposits :—			
Lloyds Bank, Birmingham		16 6 8	
" " 'Caird Gift'		35 3 10	
			51 10 6
Unexpended Balances of Grants returned			9 6 10
Dividends on Investments:—			
Consols 2½ per Cent.		81 8 0	
India 3 per Cent.		75 12 0	
Great Indian Peninsula Railway 'B' Annuity		23 4 5	
War Stock 5 per Cent.		43 3 0	
War Bonds 5 per Cent.		49 0 0	
			272 7 5
Dividends on 'Caird Fund' Investments:—			
India 3½ per Cent.		64 7 4	
Canada 3½ per Cent. (including extra ½ per Cent.)		70 0 0	
London and South-Western Railway Consolidated 4 per Cent. Preference Stock		71 5 0	
London and North-Western Railway Consolidated 4 per Cent. Preference Stock		59 17 0	
			265 9 4

Mem.—Sales of tickets for September 1919 Meeting, £45 10*s.*, are not included above.

Investments.

Nominal Amount. £ s. d.	
4,651 10 5	Consolidated 2½ per Cent. Stock
3,600 0 0	India 3 per Cent. Stock
879 14 9	Great Indian Peninsula Railway £43 'B' Annuity
2,627 0 10	India 3½ per Cent. Stock, 'Caird Fund'
2,100 0 0	London and North-Western Railway Consolidated 4 per Cent. Preference Stock, 'Caird Fund'
2,500 0 0	Canada 3½ per Cent. (1930-50) Registered Stock 'Caird Fund'
2,500 0 0	London and South-Western Railway Consolidated 4 per Cent. Preference Stock, 'Caird Fund'
96 3 6	Sir Frederick Bramwell's Gift of 2½ per Cent. Self-Cumulating Consolidated Stock
863 2 10	War Loan 5 per Cent. Stock
1,400 0 0	War Bonds 5 per Cent., 1929-47
1,000 0 0	Lloyds Bank, Birmingham—Deposit Account included in Balance at Bank, Sir J. Caird's Gift for Radio-Activity Investigation
£22,217 12 4	£4,331 5 9

Value at 30th June, 1919, £15,087 0*s.* 5*d.*

WITH THE BRITISH ASSOCIATION FOR THE *Cr.*

July 1, 1918, to June 30, 1919.

PAYMENTS.

	£	s.	d.	£	s.	d.
By Rent and Office Expenses				118	3	3
Salaries and Travelling Expenses				758	4	11
Printing, Binding, etc.				636	19	9
Grants to Research Committees :—						
Palæolithic Site in Jersey	5	0	0			
Colloid Chemistry	5	0	0			
Geophysical Discussion	10	0	0			
Physiology of Heredity	15	0	0			
Seismological Investigations	100	0	0			
Corresponding Societies Committee	25	0	0			
				160	0	0
Grants made from 'Caird Fund'				250	0	0
Balance at Lloyds Bank, Birmingham (with interest accrued), including Sir James Caird's Gift, Radio-Activity Investigation, of £1,000 and Interest accrued thereon £173 5*s.*	1,728	17	3			
Balance at Bank of England—Western Branch :—						
On 'Caird Fund' £508 19 8						
„ General Account 172 4 2						
	681	3	10			
Cash in hand	0	1	11			
	2,410	3	0			
Less Petty Cash overdrawn	2	5	2			
				2,407	17	10
				£4,331	5	9

JOHN PERRY, *General Treasurer.*

I have examined the above Account with the Books and Vouchers of the Association, and certify the same to be correct. I have also verified the Balances at the Bankers, and have ascertained that the Investments are registered in the names of the Trustees, or held by the Bank of England on account of the Association.

W. B. KEEN, *Chartered Accountant.*
August 28, 1919.

APPROVED—
EDWARD BRABROOK, *Auditor.*

Table showing the Attendances and Receipts

Date of Meeting	Where held	Presidents	Old Life Members	New Life Members
1831, Sept. 27	York	Viscount Milton, D.C.L., F.R.S.	—	—
1832, June 19	Oxford	The Rev. W. Buckland, F.R.S.	—	—
1833, June 25	Cambridge	The Rev. A. Sedgwick, F.R.S.	—	—
1834, Sept. 8	Edinburgh	Sir T. M. Brisbane, D.C.L., F.R.S.	—	—
1835, Aug. 10	Dublin	The Rev. Provost Lloyd, LL.D., F.R.S.	—	—
1836, Aug. 22	Bristol	The Marquis of Lansdowne, F.R.S.	—	—
1837, Sept. 11	Liverpool	The Earl of Burlington, F.R.S.	—	—
1838, Aug. 10	Newcastle-on-Tyne	The Duke of Northumberland, F.R.S.	—	—
1839, Aug. 26	Birmingham	The Rev. W. Vernon Harcourt, F.R.S.	—	—
1840, Sept. 17	Glasgow	The Marquis of Breadalbane, F.R.S.	—	—
1841, July 20	Plymouth	The Rev. W. Whewell, F.R.S.	169	65
1842, June 23	Manchester	The Lord Francis Egerton, F.G.S.	303	169
1843, Aug. 17	Cork	The Earl of Rosse, F.R.S.	109	28
1844, Sept. 26	York	The Rev. G. Peacock, D.D., F.R.S.	226	150
1845, June 19	Cambridge	Sir John F. W. Herschel, Bart., F.R.S.	313	36
1846, Sept. 10	Southampton	Sir Roderick I. Murchison, Bart., F.R.S.	241	10
1847, June 23	Oxford	Sir Robert H. Inglis, Bart., F.R.S.	314	18
1848, Aug. 9	Swansea	The Marquis of Northampton, Pres. R.S.	149	3
1849, Sept. 12	Birmingham	The Rev. T. R. Robinson, D.D., F.R.S.	227	12
1850, July 21	Edinburgh	Sir David Brewster, K.H., F.R.S.	235	9
1851, July 2	Ipswich	G. B. Airy, Astronomer Royal, F.R.S.	172	8
1852, Sept. 1	Belfast	Lieut.-General Sabine, F.R.S.	164	10
1853, Sept. 3	Hull	William Hopkins, F.R.S.	141	13
1854, Sept. 20	Liverpool	The Earl of Harrowby, F.R.S.	238	23
1855, Sept. 12	Glasgow	The Duke of Argyll, F.R.S.	194	33
1856, Aug. 6	Cheltenham	Prof. C. G. B. Daubeny, M.D., F.R.S.	182	14
1857, Aug. 26	Dublin	The Rev. H. Lloyd, D.D., F.R.S.	236	15
1858, Sept. 22	Leeds	Richard Owen, M.D., D.C.L., F.R.S.	222	42
1859, Sept. 14	Aberdeen	H.R.H. The Prince Consort	184	27
1860, June 27	Oxford	The Lord Wrottesley, M.A., F.R.S.	286	21
1861, Sept. 4	Manchester	William Fairbairn, LL.D., F.R.S.	321	113
1862, Oct. 1	Cambridge	The Rev. Professor Willis, M.A., F.R.S.	239	15
1863, Aug. 26	Newcastle-on-Tyne	Sir William G. Armstrong, C.B., F.R.S.	203	36
1864, Sept. 13	Bath	Sir Charles Lyell, Bart., M.A., F.R.S.	287	40
1865, Sept. 6	Birmingham	Prof. J. Phillips, M.A., LL.D., F.R.S.	292	44
1866, Aug. 22	Nottingham	William R. Grove, Q.C., F.R.S.	207	31
1867, Sept. 4	Dundee	The Duke of Buccleuch, K.C.B., F.R.S.	167	25
1868, Aug. 19	Norwich	Dr. Joseph D. Hooker, F.R.S.	196	18
1869, Aug. 18	Exeter	Prof. G. G. Stokes, D.C.L., F.R.S.	204	21
1870, Sept. 14	Liverpool	Prof. T. H. Huxley, LL.D., F.R.S.	314	39
1871, Aug. 2	Edinburgh	Prof. Sir W. Thomson, LL.D., F.R.S.	246	28
1872, Aug. 14	Brighton	Dr. W. B. Carpenter, F.R.S.	245	36
1873, Sept. 17	Bradford	Prof. A. W. Williamson, F.R.S.	212	27
1874, Aug. 19	Belfast	Prof. J. Tyndall, LL.D., F.R.S.	162	13
1875, Aug. 25	Bristol	Sir John Hawkshaw, F.R.S.	239	36
1876, Sept. 6	Glasgow	Prof. T. Andrews, M.D., F.R.S.	221	35
1877, Aug. 15	Plymouth	Prof. A. Thomson, M.D., F.R.S.	173	19
1878, Aug. 14	Dublin	W. Spottiswoode, M.A., F.R.S.	201	18
1879, Aug. 20	Sheffield	Prof. G. J. Allman, M.D., F.R.S.	184	16
1880, Aug. 25	Swansea	A. C. Ramsay, LL.D., F.R.S.	144	11
1881, Aug. 31	York	Sir John Lubbock, Bart., F.R.S.	272	28
1882, Aug. 23	Southampton	Dr. C. W. Siemens, F.R.S.	178	17
1883, Sept. 19	Southport	Prof. A. Cayley, D.C.L., F.R.S.	203	60
1884, Aug. 27	Montreal	Prof. Lord Rayleigh, F.R.S.	235	20
1885, Sept. 9	Aberdeen	Sir Lyon Playfair, K.C.B., F.R.S.	225	18
1886, Sept. 1	Birmingham	Sir J. W. Dawson, C.M.G., F.R.S.	314	25
1887, Aug. 31	Manchester	Sir H. E. Roscoe, D.C.L., F.R.S.	428	86
1888, Sept. 5	Bath	Sir F. J. Bramwell, F.R.S.	266	36
1889, Sept. 11	Newcastle-on-Tyne	Prof. W. H. Flower, C.B., F.R.S.	277	20
1890, Sept. 3	Leeds	Sir F. A. Abel, C.B., F.R.S.	259	21
1891, Aug. 19	Cardiff	Dr. W. Huggins, F.R.S.	189	24
1892, Aug. 3	Edinburgh	Sir A. Geikie, LL.D., F.R.S.	280	14
1893, Sept. 13	Nottingham	Prof. J. S. Burdon Sanderson, F.R.S.	201	17
1894, Aug. 8	Oxford	The Marquis of Salisbury, K.G. F.R.S.	327	21
1895, Sept. 11	Ipswich	Sir Douglas Galton, K.C.B., F.R.S.	214	13
1896, Sept. 16	Liverpool	Sir Joseph Lister, Bart., Pres. R.S.	330	31
1897, Aug. 18	Toronto	Sir John Evans, K.C.B., F.R.S.	120	8
1898, Sept. 7	Bristol	Sir W. Crookes, F.R.S.	281	19
1899, Sept. 13	Dover	Sir Michael Foster, K.C.B., Sec. R.S.	296	20
1900, Sept. 5	Bradford	Sir William Turner, D.C.L., F.R.S.	267	13

* Ladies were not admitted by purchased tickets until 1843. † Tickets of Admission to Sections only.

[*Continued on p.* lviii.

at Annual Meetings of the Association.

Old Annual Members	New Annual Members	Associates	Ladies	Foreigners	Total	Amount received during the Meeting	Sums paid on account of Grants for Scientific Purposes	Year
—	—	—	—	—	353.	—	—	1831
—	—	—	—	—	—	—	—	1832
—	—	—	—	—	900	—	—	1833
—	—	—	—	—	1298	—	£20 0 0	1834
—	—	—	—	—	—	—	167 0 0	1835
—	—	—	—	—	1350	—	435 0 0	1836
—	—	—	—	—	1840	—	922 12 6	1837
—	—	—	1100*	—	2400	—	932 2 2	1838
—	—	—	—	34	1438	—	1595 11 0	1839
—	—	—	—	40	1353	—	1546 16 4	1840
46	317	—	60*	—	891	—	1235 10 11	1841
75	376	33†	331*	28	1315	—	1449 17 8	1842
71	185	—	160	—	—	—	1565 10 2	1843
45	190	9†	260	—	—	—	981 12 8	1844
94	22	407	172	35	1079	—	831 9 9	1845
65	39	270	196	36	857	—	685 16 0	1846
197	40	495	203	53	1320	—	208 5 4	1847
54	25	376	197	15	819	£707 0 0	275 1 8	1848
93	33	447	237	22	1071	963 0 0	159 19 6	1849
128	42	510	273	44	1241	1085 0 0	345 18 0	1850
61	47	244	141	37	710	620 0 0	391 9 7	1851
63	60	510	292	9	1108	1085 0 0	304 6 7	1852
56	57	367	236	6	876	903 0 0	205 0 0	1853
121	121	765	524	10	1802	1882 0 0	380 19 7	1854
142	101	1094	543	26	2133	2311 0 0	480 16 4	1855
104	48	412	346	9	1115	1098 0 0	734 13 9	1856
156	120	900	569	26	2022	2015 0 0	507 15 4	1857
111	91	710	509	13	1698	1931 0 0	618 18 2	1858
125	179	1206	821	22	2564	2782 0 0	684 11 1	1859
177	59	636	463	47	1689	1604 0 0	766 19 6	1860
184	125	1589	791	15	3138	3944 0 0	1111 5 10	1861
150	57	433	242	25	1161	1089 0 0	1293 16 6	1862
154	209	1704	1004	25	3335	3640 0 0	1608 3 10	1863
182	103	1119	1058	13	2802	2965 0 0	1289 15 8	1864
215	149	766	508	23	1997	2227 0 0	1591 7 10	1865
218	105	960	771	11	2303	2469 0 0	1750 13 4	1866
193	118	1163	771	7	2444	2613 0 0	1739 4 0	1867
226	117	720	682	45‡	2004	2042 0 0	1940 0 0	1868
229	107	678	600	17	1856	1931 0 0	1622 0 0	1869
303	195	1103	910	14	2878	3096 0 0	1572 0 0	1870
311	127	976	754	21	2463	2575 0 0	1472 2 6	1871
280	80	937	912	43	2533	2649 0 0	1285 0 0	1872
237	99	796	601	11	1983	2120 0 0	1685 0 0	1873
232	85	817	630	12	1951	1979 0 0	1151 16 0	1874
307	93	884	672	17	2248	2397 0 0	960 0 0	1875
331	185	1265	712	25	2774	3023 0 0	1092 4 2	1876
238	59	446	283	11	1229	1268 0 0	1128 9 7	1877
290	93	1285	674	17	2578	2615 0 0	725 16 6	1878
239	74	529	349	13	1404	1425 0 0	1080 11 11	1879
171	41	389	147	12	915	899 0 0	731 7 7	1880
313	176	1230	514	24	2557	2689 0 0	476 8 1	1881
253	79	516	189	21	1253	1286 0 0	1126 1 11	1882
330	323	952	841	5	2714	3369 0 0	1083 3 3	1883
317	219	826	74	26 & 60 H.§	1777	1855 0 0	1173 4 0	1884
332	122	1053	447	6	2203	2256 0 0	1385 0 0	1885
428	179	1067	429	11	2453	2532 0 0	995 0 6	1886
510	244	1985	493	92	3838	4336 0 0	1186 18 0	1887
399	100	639	509	12	1984	2107 0 0	1511 0 5	1888
412	113	1024	579	21	2437	2441 0 0	1417 0 11	1889
368	92	680	334	12	1775	1776 0 0	789 16 8	1890
341	152	672	107	35	1497	1664 0 0	1029 10 0	1891
413	141	733	439	50	2070	2007 0 0	864 10 0	1892
328	57	773	268	17	1661	1653 0 0	907 15 6	1893
435	69	941	451	77	2321	2175 0 0	583 15 6	1894
290	31	493	261	22	1324	1236 0 0	977 15 5	1895
383	139	1384	873	41	3181	3228 0 0	1104 6 1	1896
286	125	682	100	41	1362	1398 0 0	1059 10 8	1897
327	96	1051	639	33	2446	2399 0 0	1212 0 0	1898
324	68	548	120	27	1403	1328 0 0	1430 14 2	1899
297	45	801	482	9	1915	1801 0 0	1072 10 0	1900

‡ Including Ladies. § Fellows of the American Association were admitted as Hon. Members for this Meeting.

[*Continued on p.* lix.

Table showing the Attendances and Receipts

Date of Meeting	Where held	Presidents	Old Life Members	New Life Members
1901, Sept. 11	Glasgow	Prof. A. W. Rücker, D.Sc., Sec.R.S.	310	37
1902, Sept. 10	Belfast	Prof. J. Dewar, LL.D., F.R.S.	243	21
1903, Sept. 9	Southport	Sir Norman Lockyer, K.C.B., F.R.S.	250	21
1904, Aug. 17	Cambridge	Rt. Hon. A. J. Balfour, M.P., F.R.S.	419	32
1905, Aug. 15	South Africa	Prof. G. H. Darwin, LL.D., F.R.S.	115	40
1906, Aug. 1	York	Prof. E. Ray Lankester, LL.D., F.R.S.	322	10
1907, July 31	Leicester	Sir David Gill, K.C.B., F.R.S.	276	19
1908, Sept. 2	Dublin	Dr. Francis Darwin, F.R.S.	294	24
1909, Aug. 25	Winnipeg	Prof. Sir J. J. Thomson, F.R.S.	117	13
1910, Aug. 31	Sheffield	Rev. Prof. T. G. Bonney, F.R.S.	293	26
1911, Aug. 30	Portsmouth	Prof. Sir W. Ramsay, K.C.B., F.R.S.	284	21
1912, Sept. 4	Dundee	Prof. E. A. Schäfer, F.R.S.	288	14
1913, Sept. 10	Birmingham	Sir Oliver J. Lodge, F.R.S.	376	40
1914, July-Sept.	Australia	Prof. W. Bateson, F.R.S.	172	13
1915, Sept. 7	Manchester	Prof. A. Schuster, F.R.S.	242	19
1916, Sept. 5	Newcastle-on-Tyne	Sir Arthur Evans, F.R.S.	164	12
1917	(No Meeting)		—	—
1918	(No Meeting)		—	—
1919, Sept. 9	Bournemouth	Hon. Sir C. Parsons, K.C.B., F.R.S.	235	47

¶ Including 848 Members of the South African Association.
‡‡ Grants from the Caird Fund are not included in this and subsequent sums.

ANALYSIS OF ATTENDANCES AT

[*The total attendances for the years* 1832,

Average attendance at 83 *Meetings* : 2130.

(The above figure includes, but the following exclude, the Australian Meeting, July-Sept., 1914.)

	Average Attendance
Average attendance at 5 Meetings beginning during *June*, *between* 1833 *and* 1860	1260
Average attendance at 4 Meetings beginning during *July*, *between* 1841 *and* 1907	1122
Average attendance at 32 Meetings beginning during *August*, *between* 1836 *and* 1911	1927
Average attendance at 40 Meetings beginning during *September*, *between* 1831 *and* 1919	1431
Attendance at 1 Meeting held in *October*, *Cambridge*, 1862	1161

Meetings beginning during August.

Average attendance at—

4	Meetings	beginning	during	the	1st	week	in	*August*	(1st– 7th)	1905
5	,,	,,	,,	,,	2nd	,,	,,	,,	(8th–14th)	2130
9	,,	,,	,,	,,	3rd	,,	,,	,,	(15th–21st)	1802
14	,,	,,	,,	,,	4th	,,	,,	,,	(22nd–31st)	1935

at Annual Meetings of the Association—(continued).

Old Annual Members	New Annual Members	Associates	Ladies	Foreigners	Total	Amount received during the Meeting	Sums paid on account of Grants for Scientific Purposes	Year
374	131	794	246	20	1912	£2046 0 0	£920 9 11	1901
314	86	647	305	6	1620	1644 0 0	947 0 0	1902
319	90	688	365	21	1754	1762 0 0	845 13 2	1903
449	113	1338	317	121	2789	2650 0 0	887 18 11	1904
937¶	411	430	181	16	2130	2422 0 0	928 2 2	1905
356	93	817	352	22	1972	1811 0 0	882 0 9	1906
339	61	659	251	42	1647	1561 0 0	757 12 10	1907
465	112	1166	222	14	2297	2317 0 0	1157 18 8	1908
290**	162	789	90	7	1468	1623 0 0	1014 9 9	1909
379	57	563	123	8	1449	1439 0 0	963 17 0	1910
349	61	414	81	31	1241	1176 0 0	922 0 0	1911
368	95	1292	359	88	2504	2349 0 0	845 7 6	1912
480	149	1287	291	20	2643	2756 0 0	978 17 1‡‡	1913
139	4160‖	539‖	—	21	5044‖	4873 0 0	1086 16 4	1914
287	116	628*	141	8	1441	1406 0 0	1159 2 8	1915
250	76	251*	73	—	826	821 0 0	715 18 10	1916
—	—	—	—	—	—	—	427 17 2	1917
—	—	—	—	—	—	—	220 13 3	1918
254	102	688	153	3	1482	1736 0 0	160 0 0	1919

** Including 137 Members of the American Association.

‖ Special arrangements were made for Members and Associates joining locally in Australia, see Report, 1914, p. 686. The numbers include 80 Members who joined in order to attend the Meeting of L'Association Française at Le Havre.

* Including Student's Tickets, 10*s*.

THE ANNUAL MEETINGS, 1831–1919.

1835, 1843, *and* 1844 *are unknown.*]

Meetings beginning during September.

Average attendance at—

		Average Attendance
15	Meetings beginning during the 1st week in *September* (1st– 7th).	1459
18	„ „ „ „ 2nd „ „ „ (8th–14th).	1693
5	„ „ „ „ 3rd „ „ „ (15th–21st).	2206
2	„ „ „ „ 4th „ „ „ (22nd–30th).	1025

Meetings beginning during June, July, and October.

Attendance at 1 Meeting (1845, June 19) beginning during the 3rd week in *June* (15th–21st)	1079
Average attendance at 4 Meetings beginning during the 4th week in *June* (22nd–30th)	1306
Attendance at 1 Meeting (1851, July 2) beginning during the 1st week in *July* (1st–7th)	710
Average attendance at 2 Meetings beginning during the 3rd week in *July* (15th–21st)	1066
Attendance at 1 Meeting (1907, July 31) beginning during the 5th week in *July* (29th–31st)	1647
Attendance at 1 Meeting (1862, October 1) beginning during the 1st week in *October* (1st–7th)	1161

Research Committees, etc., appointed by the General Committee, Meeting in Bournemouth: September, 1919.

(Names marked with an asterisk are those of Assessors or Consultative Members.)

1. *Receiving Grants of Money.*

Subject for Investigation, or Purpose	Members of Committee	Grants
Section A.—MATHEMATICS AND PHYSICS.		
Seismological Investigations.	*Chairman.*—Professor H. H. Turner. *Secretary.*—Mr. J. J. Shaw. Mr. C. Vernon Boys, Dr. J. E. Crombie, Sir Horace Darwin, Dr. C. Davison, Sir F. W. Dyson, Sir R. T. Glazebrook, Professors C. G. Knott and H. Lamb, Sir J. Larmor, Professors A. E. H. Love, H. M. Macdonald, J. Perry, and H. C. Plummer, Mr. W. E. Plummer, Professor R. A. Sampson, Sir A. Schuster, Sir Napier Shaw, Dr. G. T. Walker, and Mr. G. W. Walker.	£ 100 s. 0 d. 0
Annual Tables of Constants and Numerical Data, chemical, physical, and technological.	*Chairman.*—Sir E. Rutherford. *Secretary.*—Prof. A. W. Porter. Mr. A. E. G. Egerton.*	40 0 0
Determination of Gravity at Sea.	*Chairman.*—Professor A. E. H. Love. *Secretary.*—Dr. W. G. Duffield. Mr. T. W. Chaundy, Sir H. Darwin, Professor A. S. Eddington, Maj. E. O. Henrici, Sir A. Schuster, and Professor H. H. Turner.	10 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants £ s. d.
Radiotelegraphic Investigations.	*Chairman.*—Sir Oliver Lodge. *Secretary.*—Dr. W. H. Eccles. Mr. S. G. Brown, Dr. C. Chree, Sir F. W. Dyson, Professor A. S. Eddington, Dr. Erskine-Murray, Professors J. A. Fleming, G. W. O. Howe, H. M. Macdonald, and J. W. Nicholson, Sir H. Norman, Captain H. R. Sankey, Sir A. Schuster, Sir Napier Shaw, and Professor H. H. Turner.	100 0 0
Calculation of Mathematical Tables.	*Chairman.*— *Secretary.*–Professor J. W. Nicholson. Dr. J. R. Airey, Mr. T. W. Chaundy, Professor L. N. G. Filon, Sir G. Greenhill, Colonel Hippisley,* Professor E. W. Hobson, Mr. G. Kennedy, and Professors Alfred Lodge, A. E. H. Love, H. M. Macdonald, G. B. Mathews, G. N. Watson, and A. G. Webster.	30 0 0
To assist the work of the Tidal Institute at Liverpool.	*Chairman.*—Professor H. Lamb. *Secretary.*—Dr. A. T. Doodson. Sir S. G. Burrard,* Colonel Sir C. F. Close, Dr. P. H. Cowell, Sir H. Darwin, Dr. G. H. Fowler,* Admiral F. C. Learmonth,* Professor J. E. Petavel, Dr. J. Proudman, Major G. I. Taylor,* Professor D'Arcy W. Thompson, Sir J. J. Thomson, Professor H. H. Turner.	150 0 0
Section B.—CHEMISTRY.		
Colloid Chemistry and its Industrial Applications.	*Chairman.*—Professor F. G. Donnan. *Secretary.*—Professor W. C. McC. Lewis. Mr. E. Ardern,* Dr. E. F. Armstrong, Professor W. M. Bayliss, Mr. W. Clayton,* Prof. C. H. Desch, Mr. W. Harrison, Mr. E. Hatschek, Professors H. R. Proctor and W. Ramsden, Dr. E. J. Russell, Mr. A. B. Searle*, Dr. S. A. Shorter, Dr. H. P. Stevens, and Mr. H. B. Stocks.	5 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants £ s. d.
Fuel Economy; Utilisation of Coal; Smoke Prevention.	*Chairman.*—Professor W. A. Bone. *Vice-Chairman.*—Mr. H. James Yates. *Secretary.*—Mr. Robert Mond. Mr. A. H. Barker, Professor P. P. Bedson, Dr. W. S. Boulton, Mr. E. Bury, Professor W. E. Dalby, Mr. E. V. Evans, Dr. W. Galloway, Sir Robert Hadfield, Bart., Dr. H. S. Hele-Shaw, Mr. D. H. Helps, Dr. G. Hickling, Mr. D. V. Hollingworth, Mr. A. Hutchinson, Principal G. Knox, Mr. Michael Longridge, Professor Henry Louis, Mr. G. E. Morgans, Professor L. T. O'Shea, Mr. W. H. Patchell, Mr. E. D. Simon, Mr. A. T. Smith, Dr. J. E. Stead, Mr. C. E. Stromeyer, Mr. G. Blake Walker, Sir Joseph Walton, Professor W. W. Watts, Mr. W. B. Woodhouse, and Mr. C. H. Wordingham.	5 0 0
Absorption Spectra and Chemical Constitution of Organic Compounds.	*Chairman.*—Sir J. J. Dobbie. *Secretary.*—Professor E. E. C. Baly. Dr. A. W. Stewart.	10 0 0
Section C.—GEOLOGY.		
The Old Red Sandstone Rocks of Kiltorcan, Ireland.	*Chairman.*—Professor Grenville Cole. *Secretary.*—Professor T. Johnson. Dr. J. W. Evans, Dr. R. Kidston, and Dr. A. Smith Woodward.	15 0 0
To investigate the Geology of Coal-Seams.	*Chairman.*—Professor W. S. Boulton. *Secretary.*—Dr. W. T. Gordon. Mr. G. Barrow, Sir J. Cadman, Professor W. G. Fearnsides, Dr. J. S. Flett, Dr. Walcot Gibson, Professors J. W. Gregory and P. F. Kendall, Dr. R. Kidston, Professor T. F. Sibly, Sir A. Strahan, and Mr. J. R. R. Wilson.	15 0 0
To excavate Critical Sections in Old Red Sandstone Rocks at Rhynie, Aberdeenshire.	*Chairman.*—Dr. J. Horne. *Secretary.*—Dr. W. Mackie. Drs. J. S. Flett, W. T. Gordon, G. Hickling, R. Kidston, B. N. Peach, and D. M. S. Watson.	15 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants £ s. d.
To excavate Critical Sections in the Palæozoic Rocks of England and Wales.	*Chairman.*—Professor W. W. Watts. *Secretary.*—Professor W. G. Fearnsides. Professor W. S. Boulton, Mr. E. S. Cobbold, Professor E. J. Garwood, Mr. V. C. Illing, Dr. Lapworth, Dr. J. E. Marr, and Dr. W. K. Spencer.	30 0 0
SECTION D.—ZOOLOGY.		
Experiments in Inheritance in Silkworms.	*Chairman.*—Professor W. Bateson. *Secretary.*—Mrs. Merritt Hawkes. Dr. F. A. Dixey and Dr. L. Doncaster.	17 0 0
Experiments in Inheritance of Colour in Lepidoptera.	*Chairman.*—Professor W Bateson. *Secretary.*—The Hon. H. Onslow.* Dr. F. A. Dixey.	50 0 0
Zoological Bibliography and Publication.	*Chairman.*—Professor E. B. Poulton. *Secretary.*—Dr. F. A. Bather. Mr. E. Heron-Allen, Dr. W. E. Hoyle, and Dr. P. Chalmers Mitchell.	10 0 0
SECTION F.—ECONOMIC SCIENCE AND STATISTICS.		
The Effects of the War on Credit, Currency, Finance, and Foreign Exchanges.	*Chairman.*—Professor W. R. Scott. *Secretary.*—Mr. J. E. Allen. Professor C. F. Bastable, Sir E. Brabrook, Professor L. R. Dicksee, Mr. B. Ellinger, Mr. E. L. Franklin*, Mr. A. H. Gibson, Mr. C. W. Guilleband,* Mr. F. W. Hirst, Mr. J. M. Keynes*, Professor A. W. Kirkaldy, Mr. F. Lavington,* Mr. R. McKenna,* Mr. E. Sykes, Mr. Herbert Samuel,* Dr. J. C. Stamp,* Mr. Hartley Withers,* Mr. Hilton Young.*	100 0 0
Replacement of Men by Women in Industry.	*Chairman.*—Professor W. R. Scott. *Secretary.*—Miss Grier. Miss Ashley, Mr. J. Cunnison, Mr. Daniels, Mr. C. R. Fay, Mr. J. E. Highton, and Professor A. W. Kirkaldy.	30 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants £ s. d.
To co-operate with the National Association of Railway Travellers in obtaining better conditions of travel for members of this Association.	*Chairman.*—Sir E. Brabrook. *Secretary.*—Mr. A. H. Garstang.* Dr. W. E. Hoyle, Sir Philip Magnus.	5 0 0
SECTION G.—ENGINEERING.		
To report on certain of the more complex Stress Distributions in Engineering Materials.	*Chairman.*—Professor E. G. Coker. *Secretary.* — Professor A. F. Robertson. Professor A. Barr, Dr. Chas. Chree, Mr. Gilbert Cook, Professor W. E. Dalby, Sir J. A. Ewing, Professor L. N. G. Filon, Messrs. A. R. Fulton and J. J. Guest, Dr. B. P. Haigh, Professors J. B. Henderson, F. C. Lea, and A. E. H. Love, Dr. W. Mason, Professor J. Perry, Sir J. E. Petavel, Dr. F. Rogers, Mr. W. A. Scoble, Dr. T. E. Stanton, Mr. C. E. Stromeyer, and Mr. J. S. Wilson.	80 0 0
SECTION H.—ANTHROPOLOGY.		
To excavate a Palæolithic Site in Jersey.	*Chairman.*—Dr. R. R. Marett. *Secretary.*—Mr. G. de Gruchy. Dr. C. W. Andrews, Mr. H. Balfour, Professor A. Keith, and Colonel Warton.	5 0 0
To conduct Archæological Investigations in Malta.	*Chairman.*—Professor J. L. Myres. *Secretary.*—Dr. T. Ashby. Mr. H. Balfour, Dr. A. C. Haddon, Professor A. Keith, Dr. R. R. Marett, and Mr. H. Peake.	10 0 0
[To conduct Explorations with the object of ascertaining the Age of Stone Circles. (*Committee in suspense: grant for contingent liability.*)	*Chairman.*—Sir C. H. Read. *Secretary.*—Mr. H. Balfour. Dr. G. A. Auden, Professor Sir W. Ridgeway, Dr. J. G. Garson, Sir Arthur Evans, Dr. R. Munro, Sir W. Boyd Dawkins, Professor J. L. Myres, Mr. A. L. Lewis, and Mr. H. Peake.]	15 0 0
To report on the Distribution of Bronze Age Implements.	*Chairman.*—Professor J. L. Myres. *Secretary.*—Mr. H. Peake. Dr. E. C. R. Armstrong, Dr. H. A. Auden, Mr. H. Balfour, Mr. L. H. D. Buxton, Mr. O. G. S. Crawford, Sir W. Boyd Dawkins, Professor H. J. Fleure, Mr. G. A. Garfitt, Dr. R. R. Marett, Sir C. H. Read, Sir W. Ridgeway.	100 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants £ s. d.
To report on the Classification and Distribution of Rude Stone Monuments.	*Chairman.*—Dr. R. R. Marett. *Secretary.*—Professor H. J. Fleure. Professor J. L. Myres, Mr. H. Peake.	20 0 0
Section K.—BOTANY.		
Experimental Studies in the Physiology of Heredity.	*Chairman.*—Dr. F. F. Blackman. *Secretary.*—Miss E. R. Saunders Professors Bateson and Keeble.	40 0 0
To continue Breeding Experiments on Oenothera and other Genera.	*Chairman.*—Dr. A. B. Rendle. *Secretary.*—Dr. R. R. Gates. Professor O. V. Darbishire, Dr. M. C. Rayner, Mr. W. Brierley.	30 0 0
Section L.—EDUCATIONAL SCIENCE.		
The Effects of the 'Free-place' System upon Secondary Education.	*Chairman.*—Mr. C. A. Buckmaster. *Secretary.*—Mr. D. Berridge. Mr. C. H. Bothamley, Miss L. J. Clarke, Miss B. Foxley, Dr. W. Garnett, Sir R. A. Gregory, and Miss Walter.	10 0 0
To Enquire into the Practicability of an International Auxiliary Language.	*Chairman.*—Mr. W. B. Hardy. *Secretary.*—Dr. E. H. Tripp. Mr. E. Bullough.* Professor J. J. Findlay, Sir Richard Gregory, Dr. C. W. Kimmins, Dr. H. Foster Morley, Professor W. Ripman,* Mr. F. Nowell Smith,* Mr. A. E. Twentyman.*	5 0 0
To examine, enquire into and report upon the character, work and maintenance of Museums, with a view to their organisation and development as Institutions for Education and Research, and especially to enquire into the requirements of schools.	*Chairman.*—Professor J. A. Green. *Secretaries.*—Mr. H. Bolton, and Dr. J. A. Clubb. Dr. F. A. Bather, Rev. H. Browne, Mr. C. A. Buckmaster, Professor E. J. Garwood, Dr. A. C. Haddon, Dr. H. S. Harrison, Mr. M. D. Hill, Dr. W. E. Hoyle, Sir H. Miers, Professor P. Newberry, Mr. H. R. Rathbone, Dr. W. M. Tattersall, Sir Richard Temple, Mr. H. Hamshaw Thomas, Professor F. E. Weiss, Dr. Jessie White.	15 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants £ s. d.
To inquire into the provision of Educational Charts and Pictures for display in schools.	*Chairman.*—Professor H. E. Armstrong. *Secretary.*—Sir R. A. Gregory. Mr. D. Berridge, Miss L. J. Clarke, Mr. O. J. R. Howarth, Sir Napier Shaw, Professor H. H. Turner.	10 0 0
CORRESPONDING SOCIETIES.		
Corresponding Societies Committee for the preparation of their Report.	*Chairman.*—Mr. W. Whitaker. *Secretary.*—Mr. W. Mark Webb. Mr. P. J. Ashton, Dr. F. A. Bather, Rev. J. O. Bevan, Sir Edward Brabrook, Sir H. G. Fordham, Mr. A. L. Lewis, Mr. T. Sheppard, Rev. T. R. R. Stebbing, Mr. Mark L. Sykes, and the President and General Officers of the Association.	50 0 0

2. *Not receiving Grants of Money.*†

Subject for Investigation, or Purpose	Members of Committee
SECTION A.—MATHEMATICS AND PHYSICS.	
Investigation of the Upper Atmosphere.	*Chairman.*—Sir Napier Shaw. *Secretary.*— Mr. C. J. P. Cave, Mr. W. H. Dines, Sir R. T. Glazebrook, Sir J. Larmor, Sir J. E. Petavel, and Sir A. Schuster.
To aid the work of Establishing a Solar Observatory in Australia.	*Chairman.*—Professor H. H. Turner. *Secretary.*—Dr. W. G. Duffield. Rev. A. L. Cortie, Dr. W. J. S. Lockyer, Mr. F. McClean, and Sir A. Schuster.
SECTION B.—CHEMISTRY.	
Research on Non-Aromatic Diazonium Salts.	*Chairman.*—Dr. F. D. Chattaway. *Secretary.*—Professor G. T. Morgan. Mr. P. G. W. Bayly and Dr. N. V. Sidgwick.

† Excepting the case of Committees receiving grants from the 'Caird Fund,' for which see p. lxxii.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee
SECTION C.—GEOLOGY.	
To consider the Nomenclature of the Carboniferous, Permo-carboniferous, and Permian Rocks of the Southern Hemisphere.	*Chairman.*—Professor T. W. Edgeworth David. *Secretary.*—Professor E. W. Skeats. Mr. W. S. Dun, Professor J. W. Gregory, Sir T. H. Holland, Messrs. W. Howchin, A. E. Kitson, and G. W. Lamplugh, Dr. A. W. Rogers, Professor A. C. Seward, Mr. D. M. S. Watson, and Professor W. G. Woolnough.
The Collection, Preservation, and Systematic Registration of Photographs of Geological Interest.	*Chairman.*—Professor E. J. Garwood. *Secretary.*—Professor S. H. Reynolds. Mr. G. Bingley, Dr. T. G. Bonney, Messrs. C. V. Crook, R. Kidston, and A. S. Reid, Sir J. J. H. Teall, Professor W. W. Watts, and Messrs. R. Welch and W. Whitaker.
To consider the preparation of a List of Characteristic Fossils.	*Chairman.*—Professor P. F. Kendall. *Secretary.*—Dr. W. T. Gordon. Professor W. S. Boulton, Dr. A. R. Dwerryhouse, Professors J. W. Gregory, Sir T. H. Holland, and S. H. Reynolds, Dr. Marie C. Stopes, Dr. J. E. Marr, Professor W. W. Watts, Mr. H. Woods, and Dr. A. Smith Woodward.
To investigate the Flora of Lower Carboniferous times as exemplified at a newly-discovered locality at Gullane, Haddingtonshire.	*Chairman.*—Dr. R. Kidston. *Secretary.*—Dr. W. T. Gordon. Dr. J. S. Flett, Professor E. J. Garwood, Dr. J. Horne, and Dr. B. N. Peach.
SECTION D.—ZOOLOGY.	
To aid competent Investigators selected by the Committee to carry on definite pieces of work at the Zoological Station at Naples.	*Chairman.*—Mr. E. S. Goodrich. *Secretary.*—Dr. J. H. Ashworth. Dr. G. P. Bidder, Professor F. O. Bower, Drs. W. B. Hardy and S. F. Harmer, Professor S. J. Hickson, Sir E. Ray Lankester, Professor W. C. McIntosh, Dr. A. D. Waller.
To nominate competent Naturalists to perform definite pieces of work at the Marine Laboratory, Plymouth.	*Chairman* and *Secretary.*—Professor A. Dendy. Sir E. Ray Lankester, Professor J. P. Hill, and Mr. E. S. Goodrich.
To summon meetings in London or elsewhere for the consideration of matters affecting the interests of Zoology, and to obtain by correspondence the opinion of Zoologists on matters of a similar kind, with power to raise by subscription from each Zoologist a sum of money for defraying current expenses of the organisation.	*Chairman.*—Professor S. J. Hickson. *Secretary.*—Dr. W. M. Tattersall. Professors G. C. Bourne, A. Dendy, J. Stanley Gardiner, Marcus Hartog, W. A. Herdman, J. Graham Kerr, E. W. MacBride, Dr. P. Chalmers Mitchell, and Professor E. B. Poulton.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee
SECTION E.—GEOGRAPHY. *(See under Section H below.)*	
SECTION G.—ENGINEERING.	
The Investigation of Gaseous Explosions, with special reference to temperature.	*Chairman.*—Sir Dugald Clerk. *Secretary.*—Professor W. E. Dalby. Professors W. A. Bone, F. W. Burstall, H. L. Callendar, and E. G. Coker, Mr. D. L. Chapman, Professor H. B. Dixon, Sir R. T. Glazebrook, Dr. J. A. Harker, Colonel Sir H. C. L. Holden, Professor J. E. Petavel, Captain H. R. Sankey, Professor A. Smithells, and Mr. H. Wimperis.
To consider and report on the Standardisation of Impact Tests.	*Chairman.*—Professor W. H. Warren. *Secretary.*—Mr. J. Vicars. Professor Payne and Mr. E. H. Saniter.
SECTION H.—ANTHROPOLOGY.	
To report on the present state of knowledge of the Ethnography and Geography of Captured Territories in the Pacific.¶	*Chairman.*—Dr. W. H. R. Rivers. *Secretary.*—Professor C. G. Seligman. Mr. J. Bolton, Mr. E. W. Pearson Chinnery, Dr. A. C. Haddon, Professor L. W. Lyde, Sir E. F. im Thurn, Mr. E. A. Reeves, and Dr. W. Mersh Strong.
To report on the present state of knowledge of the Ethnography of former German Territories in Africa.	*Chairman.*—Dr. A. C. Haddon. *Secretary.*—Professor C. G. Seligman. Mr. E. S. Hartland, Sir H. H. Johnston.
To excavate Early Sites in Macedonia.	*Chairman.*—Professor Sir W. Ridgeway. *Secretary.*—Mr. A. J. B. Wace. Professor R. C. Bosanquet, Mr. L. H. D. Buxton, Mr. S. Casson, Dr. W. L. H. Duckworth, Professor J. L. Myres.
The Collection, Preservation, and Systematic Registration of Photographs of Anthropological Interest.	*Chairman.*—Sir C. H. Read. *Secretary.*—Dr. Harrison. Dr. G. A. Auden, Dr. H. O. Forbes, Mr. E. Heawood, and Professor J. L. Myres.
SECTION I.—PHYSIOLOGY.	
Electromotive Phenomena in Plants.	*Chairman.*—Dr. A. D. Waller. *Secretary.*—Mrs. Waller. Dr. F. O'B. Ellison,* Professor J. B. Farmer.
Food Standards and Man-power.	*Chairman.*—Professor W. D. Halliburton. *Secretary.*—Professor A. D. Waller. Professor E. H. Starling.

¶ Joint Committee with Section E.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee
SECTION K.—BOTANY.	
To consider the possibilities of investigation of the Ecology of Fungi, and assist Mr. J. Ramsbottom in his initial efforts in this direction.	*Chairman.*—Dr. H. W. T. Wager. *Secretaries.*—Mr. J. Ramsbottom and Miss A. Lorrain Smith. Mr. W. B. Brierley, Mr. F. T. Brooks, Mr. W. N. Cheesman, Professor T. Johnson, Professor M. C. Potter, Mr. L. Carleton Rea, and Mr. E. W. Swanton.
The Investigation of the Vegetation of Ditcham Park, Hampshire.	*Chairman.*—Mr. A. G. Tansley. *Secretary.*—Mr. R. S. Adamson. Professor R. H. Yapp.
The Structure of Fossil Plants.	*Chairman.*—Professor F. W. Oliver. *Secretary.*—Professor F. E. Weiss. Professor A. C. Seward and Dr. D. H. Scott.
To consider and report upon the necessity for Further Provision for Training and Research in Horticulture.	*Chairman.*—Professor W. Bateson. *Secretary.*—Dr. E. N. Thomas. Mr. F. T. Brooks, Dr. A. B. Rendle, and Sir Albert Rollit.
SECTION L.—EDUCATION.	
The Influence of School Books upon Eyesight.	*Chairman.*—Dr. G. A. Auden. *Secretary.*—Mr. G. F. Daniell. Mr. C. H. Bothamley, Mr. W. D. Eggar, Sir R. A. Gregory, Dr. N. Bishop Harman, Mr. J. L. Holland, Dr. W. E. Sumpner, Mr. A. P. Trotter, and Mr. Trevor Walsh.
Training in Citizenship.	*Chairman.*—Rt. Rev. J. E. C. Welldon. *Secretary.*—Lady Shaw. Sir R. Baden-Powell,* Mr. C. H. Blakiston, Mr. G. D. Dunkerley, Mr. W. D. Eggar, Mr. C. R. Fay, Principal J. C. Maxwell Garnett, Sir R. A. Gregory, and Sir T. Morison.*
CORRESPONDING SOCIETIES COMMITTEE.	
To take steps to obtain Kent's Cavern for the Nation.	*Chairman.*—Mr. W. Whitaker. *Secretary.*—Mr. W. M. Webb. Mr. Mark L. Sykes.

Research Committees 'in Suspense.'

The work of the following Committees is in suspense until further notice. The *personnel* of these Committees will be found in the Report for 1917.

SECTION B.—CHEMISTRY.

To report on the Botanical and Chemical Characters of the Eucalypts and their Correlation.

Chemical Investigation of Natural Plant Products of Victoria.

SECTION D.—ZOOLOGY.

An investigation of the Biology of the Abrolhos Islands and the North-west Coast of Australia (north of Shark's Bay to Broome), with particular reference to the Marine Fauna.

Nomenclator Animalium Genera et Sub-genera.

To obtain, as nearly as possible, a Representative Collection of Marsupials for work upon (*a*) the Reproductive Apparatus and Development, (*b*) the Brain.

SECTION E.—GEOGRAPHY.

To aid in the preparation of a Bathymetrical Chart of the Southern Ocean between Australia and Antarctica.

SECTION H.—ANTHROPOLOGY.

To conduct Explorations with the object of ascertaining the Age of Stone Circles.

To investigate and ascertain the Distribution of Artificial Islands in the Lochs of the Highlands of Scotland.

To investigate the Physical Characters of the Ancient Egyptians.

To conduct Archæological and Ethnological Researches in Crete.

The Teaching of Anthropology.

To prepare and publish Miss Byrne's Gazetteer and Map of the Native Tribes of Australia.

To conduct Anthropometric Investigations in the Island of Cyprus.

To investigate the Lake Villages in the neighbourhood of Glastonbury in connection with a Committee of the Somerset Archæological and Natural History Society.

To co-operate with Local Committees in Excavations on Roman Sites in Britain.

SECTION K.—BOTANY.

To carry out a Research on the influence of varying percentages of Oxygen and of various Atmospheric Pressures upon Geotropic and Heliotropic Irritability and Curvature.

The Renting of Cinchona Botanic Station in Jamaica.

Synopsis of Grants of Money appropriated for Scientific Purposes by the General Committee at the Bournemouth Meeting, September 1919. *The Names of Members entitled to call on the General Treasurer for Grants are prefixed to the respective Committees.*

Section A.—Mathematical and Physical Science.

	£	s.	d.
*Turner, Professor H. H.—Seismological Observations	100	0	0
*Rutherford, Sir E.—Tables of Constants	40	0	0
*Love, Professor A. E. H.—Gravity at Sea	10	0	0
*Lodge, Sir O.—Radiotelegraphic Investigations	100	0	0
*Hill, Professor M. J. M.—Mathematical Tables	30	0	0
Lamb, Professor H.—Tidal Institute at Liverpool	150	0	0

Section B.—Chemistry.

*Donnan, Professor F. G.—Colloid Chemistry	5	0	0
*Mond, Mr. R.—Fuel Economy	5	0	0
*Dobbie, Sir J. J.—Absorption Spectra, &c.	10	0	0

Section C.—Geology.

*Cole, Professor Grenville.—Old Red Sandstone Rocks of Kiltorcan	15	0	0
*Boulton, Professor W. S.—Geology of Coal Seams	15	0	0
*Horne, Dr. J.—Old Red Sandstone at Rhynie	15	0	0
*Watts, Professor W. W.—Critical Sections in Palæozoic Rocks	30	0	0

Section D.—Zoology.

*Bateson, Professor W.—Inheritance in Silkworms	17	0	0
Bateson, Professor W.—Inheritance of Colour in Lepidoptera	50	0	0
*Poulton, Professor E. B.—Zoological Bibliography.....	10	0	0

Section F.—Economic Science and Statistics.

*Scott, Professor W. R.—Effects of War on Credit, &c.	100	0	0
*Scott, Professor W. R.—Women in Industry	30	0	0
Brabrook, Sir E.—Railway Travel.....	5	0	0

Section G.—Engineering.

*Coker, Professor E. G.—Complex Stress Distributions	80	0	0

Section H.—Anthropology.

*Marett, Dr. R. R.—Palæolithic Site in Jersey	5	0	0
*Myres, Professor J. L.—Archæological Investigations in Malta.....	10	0	0
*Read, Sir C. H.—Stone Circles (*Contingent Liability*)	15	0	0
*Myres, Professor J. L.—Distribution of Bronze Age Implements	100	0	0
Marett, Dr. R. R.—Rude Stone Monuments.....	20	0	0
Carried forward	£967	0	0

* Reappointed.

	£	s.	d.
Brought forward	967	0	0
Section K.—Botany.			
*Blackman, Dr. F. F.—Physiology of Heredity	40	0	0
Rendle, Dr. A. B.—Oenothera.....	30	0	0
Section L.—Educational Science.			
*Buckmaster, Mr. C. A.—'Free-place' System	10	0	0
Hardy, Mr. W. B.—International Language.....	5	0	0
*Green, Professor J. A.—Museums	15	0	0
Armstrong, Professor H. E.—Educational Charts	10	0	0
Corresponding Societies Committee.			
*Whitaker, Mr. W.—For Preparation of Report.....	50	0	0
Total.....	£1,127	0	0

Caird Fund.

An unconditional gift of 10,000*l.* was made to the Association at the Dundee Meeting, 1912, by Mr. (afterwards Sir) J. K. Caird, LL.D., of Dundee.

The Council, in its report to the General Committee at the Birmingham Meeting, made certain recommendations as to the administration of this Fund. These recommendations were adopted, with the Report, by the General Committee at its meeting on September 10, 1913.

The following allocations have been made from the Fund by the Council to September 1919 :—

Naples Zoological Station Committee (p. lxvii).—50*l.* (1912–13); 100*l.* (1913–14); 100*l.* annually in future, subject to the adoption of the Committee's report. (Reduced to 50*l.* during war.)

Seismology Committee (p. lx).—100*l.* (1913–14); 100*l.* annually in future, subject to the adoption of the Committee's report.

Radiotelegraphic Committee (p. lxi).—500*l.* (1913–14).

Magnetic Re-survey of the British Isles (in collaboration with the Royal Society).—250*l.*

Committee on Determination of Gravity at Sea (p. lx).—100*l.* (1914–15).

Mr. F. Sargent, Bristol University, in connection with his Astronomical Work.—10*l.* (1914).

Organising Committee of Section F (Economics), towards expenses of an Inquiry into Outlets for Labour after the War.—100*l.* (1915).

Rev. T. E. R. Phillips, for aid in transplanting his private observatory.—20*l.* (1915).

Committee on Fuel Economy (p. lxii).—25*l.* (1915–16).

Sir J. K. Caird, on September 10, 1913, made a further gift of 1,000*l.* to the Association, to be devoted to the study of Radio-activity.

* Reappointed.

Resolutions and Recommendations.

The General Committee gave instructions to the General Officers upon which the following Resolutions were forwarded after the close of the meeting in Bournemouth:—

To the Prime Minister and the Chancellor of the Exchequer.

The British Association for the Advancement of Science, in reviewing the results of scientific method applied to military and other practical arts, recognises that the successful issue of the War has sprung from the efforts of scientific men concentrated on those problems, and, with the conviction that the well-being and security of the nation is dependent on the continuous study of such matters, would urge on H.M. Government the necessity for apportioning an adequate sum from that allocated to home administration and the upkeep of the fighting forces for the purpose of a definitely organised scheme of research, as, for example, on problems connected with health, food, and commerce, on explosives, on chemical warfare, and on physical and engineering problems bearing on military work.

To the First Lord of the Admiralty.

The British Association for the Advancement of Science, in reviewing the results of scientific method applied to naval and military arts, recognises that the success of our equipment has sprung from the efforts of scientific men concentrated on those problems, and, with the conviction that the security of the nation is dependent on the continuous study of such matters, would urge on H.M. Government the necessity for apportioning an adequate sum from that allocated to the upkeep of the fighting forces for the purpose of a definitely organised scheme of research on physical and engineering problems bearing on naval and military work, on explosives, and on biological and other problems related to military treatment, and to the work of the Naval Intelligence Service.

To the Secretary of State for War.

The British Association for the Advancement of Science, in reviewing the results of scientific method applied to military arts, recognises that the success of our equipment has sprung from the efforts of scientific men concentrated on those problems, and, with the conviction that the security of the nation is dependent on the continuous study of such matters, would urge on H.M. Government the necessity for apportioning an adequate sum from that allocated to the fighting forces for the purpose of a definitely organised scheme of research on explosives, on chemical warfare, on physical and engineering problems bearing on military work, and on biological and other problems related to the work of the Army Medical Service and the Military Intelligence Department.

To the President of the Board of Trade.

The British Association for the Advancement of Science, in reviewing the results of scientific method applied to practical arts, recognises that the successful issue of the War has sprung from the efforts of scientific men concentrated on those problems, and, with the conviction that the welfare of the nation and its economic recovery from the effects of the War are dependent on the continuous study of such matters, would urge on H.M. Government the necessity for apportioning an adequate sum from that allocated to the upkeep of the Board of Trade for the purpose of a definitely organised scheme of research on scientific problems relating to the objects and methods of the nation's commerce and industry.

To the Minister of Health.

The British Association for the Advancement of Science, in reviewing the results of scientific method applied to practical arts, recognises that the successful issue of the War has sprung from the efforts of scientific men concentrated on those problems, and, with the conviction that the welfare of the nation is dependent on the continuous study of such matters, would urge on H.M. Government the necessity for apportioning an adequate sum from that allocated to the upkeep of the Ministry of Health for the purpose of a definitely organised scheme of research on biological and other problems in connection with the causes and communication of disease, and the preservation of the national health.

To the Food Controller.

The British Association for the Advancement of Science, in reviewing the results of scientific method applied to practical arts, recognises that the successful issue of the War has sprung from the efforts of scientific men concentrated on those problems, and, with the conviction that the security of the nation is dependent on the continuous study of such matters, would urge on H.M. Government the necessity for apportioning an adequate sum from that allocated to the upkeep of the Ministry of Food for the purpose of a definitely organised scheme of research on scientific problems connected with the production, preservation, and distribution of foods.

Resolutions and Recommendations referred to the Council for consideration, and, if desirable, for action:—

From Section D.

That in the case of persons applying for membership of the General Committee who are not known to the Council the matter should be referred to the Organising Committee of the Section concerned.

From Section E.

The Committee of Section E recommends the Council to ask the Australian Government if they would kindly inform the British Association as to the nature and amount of the geographical and anthropological material which the Committee understands was left by the Germans in New Guinea, and if they would forward to the Association copies for any maps which they desire to base upon such material.

From Section H.

To recommend that the Council of the Association approach the Australian Government to urge that steps be taken to secure the collection and publication of German anthropological and geographical material, and other scientific data, captured in New Guinea and the adjacent enemy territories in the Pacific.

From Section H.

To recommend that the Council of the Association express to the appropriate department of His Majesty's Government their warm approval of the proposal to establish a British Institute of Archæology in Egypt with annual grants from public moneys.

From Section H.

To recommend the Council of the British Association to represent to His Majesty's Government the desirability of taking steps to secure the uniform description and nomenclature of ancient remains in respect to the Ordnance Survey of the British Isles.

From Section I.

That the Council be asked to consider the advisability of changing the name of the Section of Physiology to that of Section of Physiology and Psychology, and that the Presidents in alternate years represent the two branches of the Section.

From the Conference of Delegates of Corresponding Societies.

The Conference of Delegates of Corresponding Societies of the British Association asks that the taxes derived from motor spirit and carriages should once more be ear-marked for the improvement of the roads, and urges that in future these taxes should be entirely devoted to road improvements.

From the General Committee.

That a joint committee of the General Committee and Council be appointed to consider and advise on the future policy of the Association towards grants in aid, and the organisation of research.

(The General Committee appointed as its representatives Prof. H. E. Armstrong, Prof. A. Gray, Dr. Alex. Hill, Mr. A. G. Tansley.)

Communications ordered to be printed in extenso.

Prof. A. R. Forsyth's Paper on 'Gauss's Theorem for Quadrature and the approximate Evaluation of Definite Integrals.'

Sir G. Greenhill's Report on 'Wave Motion.'

Brig.-Gen. H. Hartley's Paper on 'Chemical Warfare.'

PUBLIC OR CITIZENS' LECTURES.

During the Meeting the following Citizens' Lectures were arranged, in co-operation with the local branch of the Workers' Educational Association in Bournemouth:—

September 9th at 7.30 P.M. in St. Andrew's Institute, Professor H. H. Turner, F.R.S., on 'Modern Astronomy.'

September 11th at 7.30 P.M. in the Technical Hall, Pokesdown, Professor S. H. Reynolds on 'Purbeck Isle and its Geology and Scenery.'

September 12th at 7.30 P.M. in the Rechabite Hall, Winton, Professor J. L. Myres on 'Women's Place in Nature from an Anthropological Standpoint.'

BRITISH MUSEUM
NATURAL HISTORY

PRESIDENT'S ADDRESS.

ADDRESS

BY

THE HON. SIR CHARLES A. PARSONS,
K.C.B., M.A., LL.D., D.Sc., F.R.S.,

PRESIDENT.

THREE years of anxiety and stress have passed since the last Meeting of the British Association. The weight of the struggle which pressed heavily upon us at the time of the Newcastle Meeting in 1916 had increased so much in intensity by the Spring of 1917 that the Council, after consultation with the Local Committee at Bournemouth, finally decided to cancel the Summer Meeting of that year. This was the first time in the history of the Association that an Annual Meeting was not held.

We all rejoice to feel that the terrible ordeal through which the whole Empire has been passing has now reached its final phases, and that during the period of reorganisation, social and industrial, it is possible to resume the Annual Meetings of the Association under happier conditions. We have gladly and with much appreciation accepted the renewed invitation of our friends and colleagues at Bournemouth.

We are gathered together at a time when, after a great upheaval, the elemental conditions of organisation of the world are still in flux, and we have to consider how to mould and influence the recrystallisation of these elements into the best forms and most economic rearrangements for the benefit of civilisation. That the British Association has exerted a great influence in guiding the nation towards advancement in the Sciences and Arts in the most general sense there can be no question, and of this we may be assured by a study of its proceedings in conjunction with the history of contemporary progress. Although the British Association cannot claim any paramount prerogative in this good work, yet it can certainly claim to provide a free arena for discussion where in the past new theories in Science, new propositions for beneficial change, new suggestions for casting aside fetters to advance-

ment in Science, Art, and Economics have first seen the light of publication and discussion.

For more than half a century it has pleaded strongly for the advancement of Science and its application to the Arts. In the yearly volume for 1855 will be found a report in which it is stated that 'The Objects for which the Association was established have been carried out in three ways: First, by requisitioning and printing reports on the present state of different branches of Science; secondly, by granting sums of money to small committees or individuals, to enable them to carry on new researches; thirdly, by recommending the Government to undertake expeditions of discovery, or to make grants of money for certain and national purposes, which were beyond the means of the Association.' As a matter of fact it has, since its commencement, paid out of its own funds upwards of 80,000*l.* in grants in aid of research.

Developments Prior to the War.

It is twenty-nine years since an engineer, Sir Frederick Bramwell, occupied this chair and discoursed so charmingly on the great importance of the next to nothing, the importance of looking after little things which, in engineering, as in other walks of life, are often too lightly considered.

The advances in engineering during the last twenty years are too many and complex to allow of their description, however short, being included in one Address, and, following the example of some of my predecessors in this chair, I shall refer only to some of the most important features of this wide subject. I feel that I cannot do better than begin by quoting from a speech made recently by Lord Inchcape, when speaking on the question of the nationalisation of coal: 'It is no exaggeration to say that coal has been the maker of modern Britain, and that those who discovered and developed the methods of working it have done more to determine the bent of British activities and the form of British society than all the Parliaments of the past hundred and twenty years.'

James Watt.—No excuse is necessary for entering upon this theme, because this year marks the hundredth anniversary of the death of James Watt, and in reviewing the past, it appears that England has gained her present proud position by her early enterprise and by the success of the Watt steam engine, which enabled her to become the first country to develop her resources in coal, and led to the establishment of her great manufactures and her immense mercantile marine.

The laws of steam which James Watt discovered are simply these: That the latent heat is nearly constant for different pressures within

the ranges used in steam engines, and that, consequently, the greater the steam pressure and the greater the range of expansion the greater will be the work obtained from a given amount of steam. Secondly, as may now seem to us obvious, that steam from its expansive force will rush into a vacuum. Having regard to the state of knowledge at the time, his conclusions appear to have been the result of close and patient reasoning by a mind endowed with extraordinary powers of insight into physical questions, and with the faculty of drawing sound practical conclusions from numerous experiments devised to throw light on the subject under investigation. His resource, courage, and devotion were extraordinary.

In commencing his investigations on the steam engine he soon discovered that there was a tremendous loss in the Newcomen engine, which he thought might be remedied. This was the loss caused by condensation of the steam on the cold metal walls of the cylinder. He first commenced by lining the walls with wood, a material of low thermal conductivity. Though this improved matters, he was not satisfied; his intuition probably told him that there should be some better solution of the problem, and doubtless he made many experiments before he realised that the true solution lay in a condenser separate from the cylinder of the engine. It is easy after discovery to say, 'How obvious and how simple!' but many of us here know how difficult is any step of advance when shrouded by unknown surroundings, and we can well appreciate the courage and the amount of investigation necessary before James Watt thought himself justified in trying the separate condenser. But to us now, and to the youngest student who knows the laws of steam as formulated by Carnot, Joule, and Kelvin, the separate condenser is the obvious means of constructing an economical condensing engine.

Watt's experiments led him to a clear view of the great importance of securing as much expansion as possible in his engines. The materials and appliances for boiler and machine construction were at that time so undeveloped that steam pressures were practically limited to a few pounds above atmospheric pressure. The cylinders and pistons of his engines were not constructed with the facility and accuracy to which we are now accustomed, and chiefly for these reasons expansion ratios of from two to threefold were the usual practice. Watt had given to the world an engine which consumed from five to seven pounds of coal per horse-power hour, or one-quarter of the fuel previously used by any engine. With this consumption of fuel its field under the conditions prevailing at the time was practically unlimited. What need was there, therefore, for commercial reasons, to endeavour still further improve the engine at the risk of encountering fresh difficulties and greater commercial embarrassments? The course was rather for him

and his partners to devote all their energy to extend the adoption of the engine as it stood, and this they did, and to the Watt engine, consuming from five to seven pounds of coal per horse-power, mankind owes the greatest permanent advances in material welfare recorded in history.

With secondary modifications, it was the prime mover in most general use for eighty years—*i.e.*, till the middle of last century. It remained for others to carry the expansion of steam still further in the compound, triple, and, lastly, in the quadruple expansion engine, which is the most economical reciprocating engine of to-day.

Watt had considered the practicability of the turbine. He writes to his partner, Boulton, in 1784: 'The whole success of the machine depends on the possibility of prodigious velocities. In short, without God makes it possible for things to move them one thousand feet per second, it cannot do us much harm.' The advance in tools of precision, and a clearer knowledge of the dynamics of rotating bodies, have now made the speeds mentioned by Watt feasible, and indeed common, everyday practice.

Turbines.—The turbine of to-day carries the expansion of steam much further than has been found possible in any reciprocating engine, and owing to this property it has surpassed it in economy of coal, and it realises to the fullest extent Watt's ideal of the expansion of steam from the boiler to the lowest vapour pressure obtainable in the condenser.

Among the minor improvements which in recent years have conduced to a higher efficiency in turbines are the more accurate curvature of the blades to avoid eddy losses in the steam, the raising of the peripheral velocities of the blades to nearly the velocity of the steam impinging upon them, and details of construction to reduce leakages to a minimum. In turbines of 20,000 to 30,000 horse-power 82 per cent. of the available energy in the steam is now obtainable as brake horse-power; and with a boiler efficiency of 85 per cent. the thermodynamic efficiency from the fuel to the electrical output of the alternator has reached 23 per cent., and shortly may reach 28 per cent., a result rivalling the efficiency of internal combustion engines worked by producer gas.

During the twenty years immediately preceding the war turbo-generators had increased in size from 500 kilowatts to 25,000 kilowatts, and the consumption of steam had fallen from 17 lb. per kw. hour to 10.3 lb. per kw. hour. Turbines have become the recognised means of generating electricity from steam on a large scale, although they have not superseded the Watt engine for pumping mines or the drawing of coal, except as a means for generating electricity for these purposes. In the same period the engine power in the mercantile marine had risen from 3,900 of the *King Edward* to 75,000 of the *Mauretania*.

As regards the Royal Navy, the engine power of battleships, prior to the war, had increased from 12,000 i.h.p. to 30,000 s.h.p., while the speed advanced from 17 knots to 23 knots, and during the war, in ships of the *Queen Elizabeth* class the power amounted to 75,000 s.h.p., with a speed of 25 knots. In cruisers similar advances were made. The i.h.p. of the *Powerful* was 25,000, while the s.h.p. of the *Queen Mary* was 78,000, with a speed of 28 knots. During the war the power obtained with geared turbines in the *Courageous* class was 100,000 s.h.p. with a speed of 32 knots, the maximum power transmitted through one gear wheel being 25,000 h.p., and through one pinion 15,500 h.p., while in destroyers, speeds up to 39 knots have been obtained. The aggregate horse-power of war and mercantile turbined vessels throughout the world is now about 35 millions.

These advances in power and speed have been made possible mainly by the successive increase in economy and diminution of weight derived from the replacement of reciprocating engines by turbines direct coupled to the propellers, and, later, by the introduction of reduction gearing between the turbines and the propellers; also by the adoption of water-tube boilers and of oil fuel. With these advances the names of Lord Fisher, Sir William White, and Sir Henry Oram will always be associated.

The British Navy has led the world for a century and more. Lord Fisher has recently said that many of the ships are already obsolete and must soon be replaced if supremacy is to be maintained; and there can be no question that, to guide the advance and development on the best lines, continuous scientific experiment, though costly at the time, will prove the cheapest in the long run.

The Work of Sir Wm. White.—With the great work of the Royal Navy fresh in our minds, we cannot but recall the prominent part taken by the late Sir William White in its construction. His sudden death, when President-elect for 1913, lost to the nation and to the Association the services of a great naval architect who possessed remarkable powers of prevision and dialectic. He was Chief Constructor to the Admiralty from 1885 to 1901, and largely to him was due the efficiency of our vessels in the Great War.

White often referred to the work of Brunel as the designer of the *Great Eastern*, and spoke of him as the originator of the cellular construction of the bottoms of ships, since universally adopted, as a means of strengthening the hull and for obtaining additional safety in case of damage. Scott Russell was the builder of this great pioneer vessel, the forerunner of the Atlantic liners, and the British Association may rightly feel satisfaction in having aided him when a young man by pecuniary grants to develop his researches into the design and con-

struction of ships and the wave-line form of hull which he originated, a form of special importance in paddle-wheel vessels.

So much discussion has taken place in the last four years as to the best construction of ship to resist torpedo attacks that it is interesting to recall briefly at the present time what was said by White in his Cantor Lectures to the Royal Society of Arts in 1906: 'Great attention has been bestowed upon means of defence against underwater torpedo attacks. From the first introduction of torpedoes it was recognised that extreme watertight subdivision in the interior of warships would be the most important means of defence. Experiments have been made with triple watertight skins forming double cellular sides, the compartments nearest the outer bottom being filled, in some cases, with water, coal, cellulose, or other materials. Armour plating has been used both on the outer bottom and on inner skins.' He also alludes to several Russian ships which were torpedoed by the Japanese, and he concludes by saying: 'Up to date the balance of opinion has favoured minute watertight subdivisions and comparatively thin watertight compartments, rather than the use of internal armour, whose use, of course, involves large expenditure of weight and cost.'

The present war has most amply confirmed his views and conclusions, then so lucidly and concisely expressed.

While on the subject of steamships, it may perhaps be opportune to say one word as to their further development. The size of ships had been steadily increasing up to the time of the war, resulting in a reduction of power required to propel them per ton of displacement. On the other hand, thanks to their greater size and more economical machinery, speeds have been increased when the traffic has justified the greater cost. The limiting factor to further increase in size is the depth of water in the harbours. With this restriction removed there is no obstacle to building ships up to 1,000 feet in length or more, provided the volume and character of the traffic are such as to justify the capital outlay.

Tungsten Steel.—Among other important pre-war developments that have had a direct bearing upon the war, mention should be made of the discovery and extensive use of alloys of steel. The wonderful properties conferred upon steel by the addition of tungsten were discovered by Muschet [1] in 1868, and later this alloy was investigated and improved by Maunsel White and Taylor, of Philadelphia. The latter showed that the addition of tungsten to steel has the following effect: That after the steel has been quenched at a very high temperature near its melting point it can be raised to a much higher temperature than is possible with ordinary carbon tool steel, without losing its hardness

[1] Who has not been sufficiently credited with his share in making the Bessemer process a practical success.

and power of cutting metal. In other words, it holds the carbon more tenaciously in the hardened state, and hence tungsten steel tools, even when red hot, can cut ordinary mild steel. It has revolutionised the design of machine tools and has increased the output on heavy munition work by 100 per cent., and in ordinary engineering by 50 per cent.

The alloys of steel and manganese with which the name of Sir Robert Hadfield is associated have proved of utility in immensely increasing the durability of railway and tramway points and crossings, and for the hard teeth of machinery for the crushing of stone and other materials, and, in fact, for any purposes where great hardness and strength are essential.

Investigation of Gaseous Explosions.—Brief reference must also be made—and it will be gratifying to do so—to the important work of one of the Committees of the British Association appointed in 1908, under the chairmanship of the late Sir William Preece, for the investigation of gaseous explosions, with special reference to temperature. The investigations of the Committee are contained in seven yearly reports up to 1914. Of the very important work of the Committee I wish to refer to one investigation in particular, which has proved to be a guiding star to the designers and manufacturers of internal combustion engines in this country. The members of the Committee more directly associated with this particular investigation were Sir Dugald Clerk, Professor Callendar, and the late Professor Bertram Hopkinson.

The investigation showed that the intensity of the heat radiated by the incandescent gases to the walls of the cylinder of a gas engine increases with the size of the cylinder, the actual rate of this increase being approximately proportional to the square root of the depth of the radiating incandescent gas; the intensity was also shown to increase rapidly with the richness of the gas. It suffices now to say that the heat in a large cylinder with a rich explosive mixture is so intense that the metal eventually cracks. The investigation shows why this occurs, and by doing so has saved enormous sums to the makers of gas and oil engines in this country, and has led them to avoid the large cylinder, so common in Germany before the war, in favour of a multiplicity of smaller cylinders.

Science and the War.

In coming to this section of my Address I am reminded that in the course of his Presidential Address to Section G, in 1858, Lord Rosse said: 'Another object of the Mechanical Section of the Association has been effected—the importance of engineering science in the service of the State has been brought more prominently forward. There seems, however, something still wanting. Science may yet do more for the Navy and Army if more called upon.'

Comparatively recently, too, Lord French remarked: 'We have failed during the past to read accurately the lessons as regards the fighting of the future which modern science and invention should have taught us.'

In view of the eminent services which scientists have rendered during the war, I think that we may be justified in regarding the requirement stated by Lord Rosse as having at last been satisfied, and also in believing that such a criticism as Lord French rightly uttered will not be levelled against the country in the future.

Though British men of Science had not formerly been adequately recognised in relation to war and the safety of their country, yet at the call of the sailors and the soldiers they whole-heartedly, and with intense zeal, devoted themselves to repair the negligence of the past, and to apply their unrivalled powers and skill to encounter and overcome the long-standing machinations of the enemy. They worked in close collaboration with the men of Science of the Allied Nations, and eventually produced better war material, chemicals, and apparatus of all kinds for vanquishing the enemy and the saving of our own men than had been devised by the enemy during many years of preparation planned on the basis of a total disregard of treaties and the conventions of war.

Four years is too short a time for much scientific invention to blossom to useful maturity, even under the forced exigencies of war and Government control. It must be remembered that in the past the great majority of new discoveries and inventions of merit have taken many years—sometimes generations—to bring them into general use. It must also be mentioned that in some instances discoveries and inventions are attributable to the general advance in Science and the Arts which has brought within the region of practical politics an attack on some particular problem. So the work of the scientists during the war has perforce been directed more to the application of known principles, trade knowledge, and properties of matter to the waging of war, than to the making of new and laborious discoveries; though, in effecting such applications, inventions of a high order have been achieved, some of which promise to be of great usefulness in time of peace.

The advance of Science and the Arts in the last century had, however, wrought a great change in the implements of war. The steam engine, the internal combustion engine, electricity, and the advances in metallurgy and chemistry had led to the building up of immense industries which, when diverted from their normal uses, have produced unprecedented quantities of war material for the enormous armies, and also for the greatest Navy which the world has ever seen.

The destructive energy in the field and afloat has multiplied many hundredfold since the time of the Napoleonic wars; both before and

during the war the size of guns and the efficiency of explosives and shell increased immensely, and many new implements of destruction were added. Modern Science and Engineering enabled armies unprecedented in size, efficiency and equipment to be drawn from all parts of the world and to be concentrated rapidly in the fighting line.

To build up the stupendous fighting organisation, ships have been taken from their normal trade routes, locomotives and material from the home railways, the normal manufactures of the country have been largely diverted to munitions of war; the home railways, tramways, roads, buildings and constructions, and material of all kinds have been allowed to depreciate. The amount of depreciation in roads and railways alone has been estimated at 400 millions per annum at present prices. Upon the community at home a very great and abnormal strain has been thrown, notwithstanding the increased output per head of the workers derived from modern methods and improved machinery. In short, we have seen for the first time in history nearly the whole populations of the principal contending nations enlisted in intense personal and collective effort in the contest, resulting in unprecedented loss of life and destruction of capital.

A few figures will assist us to realise the great difference between this war and all preceding wars. At Waterloo, in 1815, 9,044 artillery rounds were fired, having a total weight of 37·3 tons, while on one day during the last offensive in France, on the British Front alone, 943,837 artillery rounds were fired, weighing 18,080 tons—over 100 times the number of rounds, and 485 times the weight of projectiles. Again, in the whole of the South African War, 273,000 artillery rounds were fired, weighing approximately 2,800 tons; while during the whole war in France, on the British Front alone, over 170 million artillery rounds were fired, weighing nearly $3\frac{1}{2}$ million tons—622 times the number of rounds, and about 1,250 times the weight of projectiles.

However great these figures in connection with modern land artillery may be, they become almost insignificant when compared with those in respect of a modern naval battle squadron. The *Queen Elizabeth* when firing all her guns discharges 18 tons of metal and develops 1,870,000 foot-tons of energy. She is capable of repeating this discharge once every minute, and when doing so develops by her guns an average of 127,000 effective horse-power, or more than one-and-a-half times the power of her propelling machinery; and this energy is five times greater than the maximum average energy developed on the Western Front by British guns. Furthermore, if all her guns were fired simultaneously, they would for the instant be developing energy at the rate of 13,132,000 horse-power. From these figures we can form some conception of the vast destructive energy developed in a modern naval battle.

Engineering and the War.

With regard to the many important engineering developments made during the war, several papers by authorities are announced in the syllabus of papers constituting the sectional proceedings of this year's Meeting. Among them are 'Tanks,' by Sir Eustace d'Eyncourt; 'Scientific Progress of Aviation during the War,' by Dr. Bairstow; 'Airships,' by Lieut.-Col. Cave-Brown-Cave; 'Directional Wireless, with Special Reference to Aircraft,' by Capt. Robinson; 'Wireless in Aircraft,' by Major Erskine Murray; 'Wireless Telegraphy during the First Three Years of the War,' by Major Vincent Smith; 'Submarine Mining,' by Com. Gwynne; 'Emergency Bridge Construction,' by Prof. Ingles; and 'The Paravane,' by Com. Burney. Accordingly, it is quite unnecessary here to particularise further except in the few following instances:—

Sound-ranging and Listening Devices.—Probably the most interesting development during the war has been the extensive application of sound-listening devices for detecting and localising the enemy. The Indian hunter puts his ear to the ground to listen for the sound of the footsteps of his enemy. So in modern warfare science has placed in the hands of the sailor and soldier elaborate instruments to aid the ear in the detection of noises transmitted through earth, water, air, or ether, and also in some cases to record these sounds graphically or photographically, so that their character and the time of their occurrence may be tabulated.

The sound-ranging apparatus by which the position of an enemy gun can be determined from electrically recorded times at which the sound wave from the gun passes over a number of receiving stations, has enabled our artillery to concentrate their fire on the enemy's guns, and often to destroy them.

The French began experimenting in September 1914 with methods of locating enemy guns by sound. The English section began work in October 1915, adopting the French methods in the first instance. By the end of 1916 the whole Front was covered, and sound-ranging began to play an important part in the location of enemy batteries. During 1917 locations by sound-ranging reached about 30,000 for the whole army, this number being greater than that given by any other means of location. A single good set of observations could be relied upon to give the position of an enemy gun to about 50 yards at 7,000 yards' range. It could also be carried on during considerable artillery activity.

The apparatus for localising noises transmitted through the ground has been much used for the detection of enemy mining and counter-

mining operations. Acoustic tubes, microphones, and amplifying valves have been employed to increase the volume of very faint noises.

For many years before the war the Bell Submarine Signalling Company, of which Sir William White was one of the early directors, used submerged microphones for detecting sound transmitted through the water, and a submerged bell for sending signals to distances up to one mile. With this apparatus passing ships could be heard at a distance of nearly a mile when the sea was calm and the listening vessel stationary.

Of all the physical disturbances emitted or produced by a moving submarine, those most easily detected, and at the greatest distance, are the pressure waves set up in the water by vibrations produced by the vessel and her machinery. A great variety of instruments have been devised during the war for detecting these noises, depending on microphones and magnetophones of exceedingly high sensitivity. Among them may be particularly mentioned the hydrophones devised by Captain Ryan and Professor Bragg, being adaptations of the telephone transmitter to work in water, instead of air. These instruments, when mounted so as to rotate, are directional, being insensitive to sound waves whose front is perpendicular to the plane of the diaphragm, and giving the loudest sound when the diaphragm is parallel to the wave front.

Another preferable method for determining direction is to use two hydrophones coupled to two receivers, one held to each ear. This is called the biaural method, and enables the listener to recognise the direction from which the sound emanates.

When the vessel is in motion or the sea is rough the water noises from the dragging of the instrument through the water and from the waves striking the ship drown the noises from the enemy vessel, and under such conditions the instruments are useless. The assistance of eminent biologists was of invaluable help at this juncture. Experiments were made with sea-lions by Sir Richard Paget, who found that they have directional hearing under water up to speeds of six knots. Also Professor Keith explained the construction of the hearing organs of the whale, the ear proper being a capillary tube, too small to be capable of performing any useful function in transmitting sound to the relatively large aural organs, which are deep set in the head. The whale therefore hears by means of the sound waves transmitted through the substance of the head. It was further seen that the organs of hearing of the whale to some degree resembled the hydrophone.

The course now became clear. Hollow towing bodies in the form of fish or porpoises were made of celluloid, varnished canvas, or very thin metal, and the hydrophone suitably fixed in the centre of the head. The body is filled with water, and the cable towing the fish contains the insulated leads to the observer on board the vessel. When

towed at some distance behind the chasing ship disturbing noises are small, and enemy noises can be heard up to speeds of 14 knots, and at considerable distances. Thermionic amplifying valves have been extensively used, and have added much to the sensitiveness of the hydrophone in its many forms.

After the loss of the *Titanic* by collision with an iceberg, Lewis Richardson was granted two patents in 1912 for the detection of above-water objects by their echo in the air, and underwater objects by their echo transmitted through the water. The principles governing the production and the concentration of beams of sound are described in his specifications, and he recommends frequencies ranging from 4,786 to 100,000 complete vibrations per second, and also suggests that the rate of approach or recession from the object may be determined from the difference in the pitch of the echo from the pitch of the blast sent out. Hiram Maxim also suggested similar apparatus a little later.

The echo method of detection was not, however, practically developed until French and English scientists, with whom was associated Professor Langevin, of the Collège de France, realising its importance for submarine detection, brought the apparatus to a high degree of perfection and utility shortly before the Armistice. Now, with beams of high-frequency sound waves, it is possible to sweep the seas for the detection of any submerged object, such as icebergs, submarines, surface vessels, and rocks; they may also be used to make soundings. It enables a chasing ship to pick up and close in on a submarine situated more than a mile away.

The successful development of sound-ranging apparatus on land led to the suggestion by Professor Bragg that a modified form could be used to locate under-water explosions. It has been found that the shock of an explosion can be detected hundreds of miles from its source by means of a submerged hydrophone, and that the time of the arrival of the sound wave can be recorded with great precision. At the end of the war the sound-ranging stations were being used for the detection of positions at sea, required for strategical purposes. The same stations are now being used extensively for the determination of such positions at sea as light-vessels, buoys which indicate channels, and obstructions such as sunken ships. By this means ships steaming in fog can be given their positions with accuracy for ranges up to 500 miles.

Among the many other important technical systems and devices brought out during the war which will find useful application under peace conditions as aids to navigation I may mention directional wireless, by which ships and aircraft can be given their positions and directed, and on this subject we are to have a paper in Section G.

Leader gear, first used by the Germans to direct their ships through their minefields, and subsequently used by the Allies, consists of an

insulated cable laid on the bottom of the sea, earthed at the further end, and through which an alternating current is passed. By means of delicate devices installed on a ship, she is able to follow the cable at any speed with as much precision as a railless electric 'bus can follow its trolley wire. Cables up to 50 miles long have been used, and this device promises to be invaluable to ships navigating narrow and tortuous channels and entering or leaving harbours in a fog.

Aircraft.—It may be justly said that the development in aircraft design and manufacture is one of the astonishing engineering feats of the war. In August 1914 the British Air Services possessed a total of 272 machines, whereas in October 1918, just prior to the Armistice, the Royal Air Force possessed over 22,000 effective machines. During the first twelve months of the war the average monthly delivery of aeroplanes to our Flying Service was fifty, while during the last twelve months of the war the average deliveries were 2,700 per month. So far as aero-engines are concerned, our position in 1914 was by no means satisfactory. We depended for a large proportion of our supplies on other countries. In the Aerial Derby of 1913, of the eleven machines that started, not one had a British engine. By the end of the war, however, British aero-engines had gained the foremost place in design and manufacture, and were well up to requirements as regards supply. The total horse-power produced in the last twelve months of the war approximated to eight millions of brake horse-power, a figure quite comparable with the total horse-power of the marine engine output of the country.[2]

Much might be written on the progress in aircraft, but the subject will be treated at length in the sectional papers. In view of the recent trans-Atlantic flights, however, I feel that it may be opportune to make the following observations on the comparative utility of aeroplanes and airships for commercial purposes. In the case of the aeroplane, the weight per horse-power increases with the size, other things being equal. This increase, however, is met to some extent by a multiplicity of engines, though in the fusilage the increase remains.

On the other hand, with the airship the advantage increases with the size, as in all ships. The tractive effort per ton of displacement diminishes in inverse proportion to the dimensions, other things, including the speed, being the same. Thus, an airship of 750 feet length and 60 tons displacement may require a tractive force of 5 per cent., or 3 tons, at 60 miles per hour; while one of 1,500 feet in length and $8 \times 60 = 480$ tons displacement would only require $2\frac{1}{2}$ per cent. $\times 480 = 12$ tons at the same speed, and would carry fuel for double the distance.

[2] See Lord Weir's Paper read at the Victory Meeting of the North-East Coast Institution of Engineers and Shipbuilders, July 1919.

With the same proportion of weight of hull to displacement, the larger airship would stand double the wind pressure, and would weather storms of greater violence and hailstones of greater size. It would be more durable, the proportional upkeep would be less, and the proportional loss of gas considerably less. In other words, it would lose a less proportion of its buoyancy per day. It is a development in which success depends upon the project being well thought out and the job being thoroughly well done. The equipment of the airsheds with numerous electric haulage winches, and all other appliances to make egress and ingress to the sheds safe from danger and accident, must be ample and efficient.

The airship appears to have a great future for special commerce where time is a dominant factor and the demand is sufficient to justify a large airship. It has also a great field in the opening up of new countries where other means of communication are difficult. The only limitation to size will be the cost of the airship and its sheds, just as in steam vessels it is the cost of the vessels and the cost of deepening the harbours that limit the size of Atlantic liners.

Such developments generally take place slowly, otherwise failures occur—as in the case of the *Great Eastern*—and it may be many years before the airship is increased from the present maximum of 750 feet to 1,500 feet with success, but it will assuredly come. If, however, the development is subsidised or assisted by Government, incidental failures may be faced with equanimity and very rapid development accomplished.[3] In peace time the seaplane, aeroplane, and airship will most certainly have their uses. But, except for special services of high utility, it is questionable whether they will play more than a minor part as compared with the steamship, railway, and motor transport.

Electricity.—The supply and use of electricity has developed rapidly in recent years. For lighting it is the rival of gas, though each has its advantages. As a means of transmitting power over long distances it has no rival, and its efficiency is so high that when generated on a large scale and distributed over large areas it is a cheap and reliable source of power for working factories, tramways, suburban railways, and innumerable other purposes, including metallurgical and chemical processes. It is rapidly superseding locally generated steam-power, and is a rival to the small and moderate-sized gas and oil engine. It has made practicable the use of water-power through the generation of electricity in bulk at the natural falls, from which the power is transmitted to the consumers, sometimes at great distances.

[3] The literature on this subject includes an article which appeared in *Engineering* on January 3, 1919.

Fifteen years ago electricity was generated chiefly by large reciprocating steam engines, direct coupled to dynamos or alternators, but of late years steam turbines have in most instances replaced them, and are now exclusively used in large generating stations, because of their smaller cost and greater economy in fuel. The size of the turbines may vary from a few thousand horse-power up to about 50,000 horse-power. At the end of last year the central electric stations in the United Kingdom contained plant aggregating $2\frac{3}{4}$ million kilowatts, 79 per cent. of which was driven by steam turbines.

Much discussion has taken place as to the most economical size of generating stations, their number, the size of the generating units, and the size of the area to be supplied. On the one hand, a comparatively small number of very large or super-stations, instead of a large number of moderate-sized stations dotted over the area, results in a small decrease in the cost of production of the electricity, because in the super-stations larger and slightly more economical engines are employed, while the larger stations permit of higher organisation and more elaborate labour-saving appliances. Further, if in the future the recovery of the by-products of coal should become a practical realisation as part of the process in the manufacture of the electric current, the larger super-stations present greater facilities than the smaller stations. On the other hand, super-stations involve the transmission of the electricity over greater distances, and consequently greater capital expenditure and cost of maintenance of mains and transmission apparatus, and greater electrical transmission losses, while the larger generating unit takes longer to overhaul or repair, and consequently a larger percentage of spare plant is necessary.

The greatest element in reducing the cost of electricity is the provision of a good load factor; in other words, the utilisation of the generating plant and mains to the greatest extent during the twenty-four hours of each day throughout the year. This is a far more important consideration than the size of the station, and it is secured to the best advantage in most cases by a widespread network of mains, supplying a diversity of consumers and uses, each requiring current at different times of the day. The total load of each station being thus an average of the individual loads of a number of consumers is, in general, far less fluctuating than in the case of small generating and distributing systems, which supply principally one class of consumer, a state of affairs that exists in London, for instance, at the present time. It is true that there may be exceptional cases, such as at Kilmarnock, where a good load factor may be found in a small area, but in this case the consumers are chiefly mills, which require current for many hours daily.

There is no golden rule to secure cheap electricity. The most

favourable size, locality, and number of generating stations in each area can only be arrived at by a close study of the local conditions, but there is no doubt that, generally speaking, to secure cheap electricity a widespread network of mains is in most cases a very important, if not an essential, factor.

The electrification of tramways and suburban railways has been an undoubted success where the volume of traffic has justified a frequent service, and it has been remarkable that where suburban lines have been worked by frequent and fast electrical trains there has resulted a great growth of passenger traffic. The electrification of main line railways would no doubt result in a saving of coal; at the same time, the economical success would largely depend on the broader question as to whether the volume of the traffic would suffice to pay the working expenses, and provide a satisfactory return on the capital.

Municipal and company generating stations have been nearly doubled in capacity during the war to meet the demand from munition works, steel works, chemical works, and for many other purposes. The provision of this increased supply was an enormous help in the production of adequate munitions. At the commencement of the war there were few steel electric furnaces in the country; at the end of last year 117 were at work, producing 20,000 tons of steel per month, consisting chiefly of high-grade ferro alloys used in munitions.

The Future.

The nations who have exerted the most influence in the war have been those who have developed to the greatest extent their resources, their manufactures, and their commerce. As in the war, so in the civilisation of mankind. But, viewing the present trend of developments in harnessing water-power and using up the fuel resources of the world for the use and convenience of man, one cannot but realise that, failing new and unexpected discoveries in science, such as the harnessing of the latent molecular and atomic energy in matter, as foreshadowed by Clerk Maxwell, Kelvin, Rutherford, and others, the great position of England cannot be maintained for an indefinite period. At some time more or less remote—long before the exhaustion of our coal—the population will gradually migrate to those countries where the natural sources of energy are the most abundant.

Water-power and Coal.—The amount of available water-power in the British Isles is very small as compared with the total in other countries. According to the latest estimates, the total in the British Isles is under 1½ million horse-power, whereas Canada alone possesses over 20 millions, of which over 2 millions have already been harnessed. In the rest of the British Empire there are upwards of 30 millions and in the remainder of the world at least 150 millions, so that England

herself possesses less than 1 per cent. of the water-power of the world. Further, it has been estimated that she only possesses $2\frac{1}{2}$ per cent. of the whole coal of the world. To this question I would wish to direct our attention for a few minutes.

I have said that England owes her modern greatness to the early development of her coal. Upon it she must continue to depend almost exclusively for her heat and source of power, including that required for propelling her vast mercantile marine. Nevertheless, she is using up her resources in coal much more rapidly than most other countries are consuming theirs, and long before any near approach to exhaustion is reached her richer seams will have become impoverished, and the cost of mining so much increased that, given cheap transport, it might pay her better to import coal from richer fields of almost limitless extent belonging to foreign countries, and workable at a much lower cost than her own.

Let us endeavour to arrive at some approximate estimate of the economic value of the principal sources of power. The present average value of the royalties on coal in England is about 6*d.* per ton, but to this must be added the profit derived from mining operations after paying royalties and providing for interest on the capital expended and for its redemption as wasting capital. After consultation with several leading experts in these matters, I have come to the conclusion that about 1*s.* per ton represents the pre-war market value of coal in the seams in England.

It must, however, be remembered that, in addition, coal has a considerable value as a national asset, for on it depends the prosperity of the great industrial interests of the country, which contribute a large portion of the wealth and revenue. From this point of view the present value of unmined coal seems not to have been sufficiently appreciated in the past, and that in the future it should be better appraised at its true value to the nation.

This question may be viewed from another aspect by making a comparison of the cost of producing a given amount of electrical power from coal and from water-power. Assuming that one horse-power of electrical energy maintained for one year had a pre-war value of 5*l.*, and that it requires about eight tons of average coal to produce it, we arrive at the price of 6*s.* 3*d.* per ton—*i.e.*, crediting the coal with half the cost. The capital required to mine eight tons of coal a year in England is difficult to estimate, but it may be taken approximately to be 5*l.*, and the capital for plant and machinery to convert it into electricity at 10*l.*, making a total of 15*l.* In the case of water-power the average capital cost on the above basis is 40*l.*, including water rights (though in exceptionally favoured districts much lower costs are recorded).

From these figures it appears that the average capital required to produce electrical power from coal is less than one half the amount that is required in the case of water-power. The running costs, however, in connection with water-power are much less than those in respect of coal. Another interesting consideration is that the cost of harnessing all the water-power of the world would be about 8,000 millions, or equal to the cost of the war to England.

Dowling has estimated the total coal of the world as over seven million million tons, and whether we appraise it at 1*s.* or more per ton its present and prospective value is prodigious. For instance, at 6*s.* 3*d.* per ton it amounts to nearly one hundred times the cost of the war to all the belligerents.

In some foreign countries the capital costs of mining are far below the figures I have taken, and, as coal is transportable over long distances and, generally speaking, electricity is not so at present, therefore it seems probable that capital will in the immediate future flow in increasing quantity to mining operations in foreign countries rather than to the development of the more difficult and costly water-power schemes. When, however, capital becomes more plentiful the lower running costs of water-power will prevail, with the result that it will then be rapidly developed.

As to the possible new sources of power, I have already mentioned molecular energy, but there is another alternative which appears to merit attention.

Bore Hole.—In my address to Section G in 1904 I discussed the question of sinking a shaft to a depth of twelve miles, which is about ten times the depth of any shaft in existence. The estimated cost was 5,000,000*l.*, and the time required about eighty-five years.

The method of cooling the air-locks to limit the barometric pressure on the miners and other precautions were described, and the project appeared feasible. One essential factor has, however, been queried by some persons: Would the rock at the great depth crush in and destroy the shaft? Subsequent to my address, I wrote a letter to *Nature*, suggesting that the question might be tested experimentally. Professor Frank D. Adams, of McGill University, Montreal, acting on the suggestion, has since carried out exhaustive experiments, published in the *Journal of Geology* for February 1912, showing that in limestone a depth of fifteen miles is probably practicable, and that in granite a depth of thirty miles might be reached.

Little is at present known of the earth's interior, except by inference from a study of its surface, upturned strata, shallow shafts, the velocity of transmission of seismic disturbances, its rigidity and specific gravity, and it seems reasonable to suggest that some attempt should be made

to sink a shaft as deep as may be found practicable and at some locality selected by geologists as the most likely to afford useful information.

When we consider that the estimated cost of sinking a shaft to a depth of twelve miles, at present-day prices, is not much more than the cost of one day of the war to Great Britain alone, the expense seems trivial as compared with the possible knowledge that might be gained by an investigation into this unexplored region of the earth. It might, indeed, prove of inestimable value to Science, and also throw additional light on the internal constitution of the earth in relation to minerals of high specific gravity.

In Italy, at Lardarello, bore-holes have been sunk, which discharge large volumes of high-pressure steam, which is being utilised to generate about 10,000 horse-power by turbines. At Solfatara, near Naples, a similar project is on foot to supply power to the great works in the district. It seems, indeed, probable that in volcanic regions a very large amount of power may be, in the future, obtained directly or indirectly by boring into the earth, and that the whole subject merits the most careful consideration.

While on the subject of obtaining power, may I digress for a few moments and describe an interesting phenomenon of a somewhat converse nature—*viz.* that of intense pressure produced by moderate forces closing up cavities in water.

A Committee was appointed by the Admiralty in 1916 to investigate the cause of the rapid erosion of the propellers of some of the ships doing arduous duties. This was the first time that the problem had been systematically considered. The Committee found that the erosion was due to the intense blows struck upon the blades of the propellers by the nuclei of vacuous cavities closing up against them. Though the pressure bringing the water together was only that of the atmosphere, yet it was proved that at the nucleus 20,000 atmospheres might be produced.

The phenomenon may be described as being analagous to the well-known fact that nearly all the energy of the arm that swings it is concentrated in the tag of a whip. It was shown that when water flowed into a conical tube which had been evacuated a pressure of over 140 tons per square inch was recorded at the apex, which was capable of eroding brass, steel, and in time even the hardest steel. The phenomenon may occur under some conditions in rivers and waterfalls where the velocity exceeds 50 feet per second, and it is probably as great a source of erosion as by the washing down of boulders and pebbles. Then again, when waves beat on a rocky shore, under some conditions, intense hydraulic pressures will occur, quite sufficient of themselves to crush the rock and to open out narrow fissures into caves.

Research.—The whole question of the future resources of the Empire

is, I venture to think, one which demands the serious attention of all scientists. It should be attacked in a comprehensive manner, and with that insistence which has been so notable in connection with the efforts of British investigators in the past. In such a task, some people might suggest, we need encouragement and assistance from the Government of the country. Surely we have it. As many here know, a great experimental step towards the practical realisation of Solomon's House as prefigured by Francis Bacon in the *New Atlantis* is being made by the Government at the present time. The inception, constitution, and methods of procedure of the Department, which was constituted in 1915, were fully described by Sir Frank Heath in his paper to the Royal Society of Arts last February, and it was there stated by Lord Crewe that, so far as he knew, this was the only country in which a Government Department of Research existed.[4]

It is obvious that the work of a Department of this kind must be one of gradual development with small beginnings, in order that it may be sound and lasting. The work commenced by assisting a number of researches conducted by scientific and professional societies which were languishing as a result of the war, and grants were also made to the National Physical Laboratory and to the Central School of Pottery at Stoke-on-Trent. The grants for investigation and research for the year 1916-17 totalled 11,055*l.*, and for the present year are anticipated to be 93,570*l.* The total income of the National Physical Laboratory in 1913-14 was 43,713*l.*, and owing to the great enlargement of the Laboratory the total estimate of the Research Department for this service during the current year is 154,650*l.*

Another important part of the work of the Department has been to foster and to aid financially Associations of the trades for the purpose of research. Nine of these Associations are already at work; eight more are approved, and will probably be at work within the next two months; and another twelve are in the earlier stage of formation. There are also signs of increased research by individual factories. Whether this is due to the indirect influence of the Research Department or to a change in public opinion and a more general recognition of the importance of scientific industrial research it is difficult to say.

The possibility of the uncontrolled use on the part of a nation of the power which Science has placed within its reach is so great a menace to civilisation [5] that the ardent wish of all reasonable people is to possess some radical means of prevention through the establishment

[4] The Italian Government are now, however, establishing a National Council for Research, and a Bill is before the French Chamber for the establishment of a National Office of Scientific, Industrial, and Agricultural Research and Inventions.

[5] For instance, it might some day be discovered how to liberate instantaneously the energy in radium, and radium contains 2½ million times the energy of the same weight of T.N.T.

of some form of wide and powerful control. Has not Science forged the remedy, by making the world a smaller arena for the activities of civilisation, by reducing distance in terms of time? Alliances and unions, which have successfully controlled and stimulated republics of heterogeneous races during the last century, will therefore have become possible on a wider and grander scale, thus uniting all civilised nations in a great League to maintain order, security, and freedom for every individual, and for every State and nation liberty to devote their energies to the controlling of the great forces of Nature for the use and convenience of man, instead of applying them to the killing of each other.

Many of us remember the President's Banner at the Manchester Meeting in 1915, where Science is allegorically represented by a sorrowful figure covering her eyes from the sight of the guns in the foreground. This year Science is represented in her more joyful mien, encouraging the arts and industries. It is to be sincerely hoped that the future will justify our present optimism.

REPORTS

ON THE

STATE OF SCIENCE, ETC.

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Reports on Physical Sciences for which World-wide Observations are important.

At a meeting of the Organising Committee of Section A, held on May 11, 1916, the following Resolution was passed:—

That the Organising Committee of Section A endeavour to obtain a series of Reports on the present state and prospects of those sciences for which world-wide observations are important, such reports to aim at:—

(*a*) A brief statement of present achievements.
(*b*) A specification of problems immediately pressing.
(*c*) A further specification of problems which should be considered in the near future, though not perhaps immediately.

This Resolution would apply in the cases of:—

1. *Geodesy and Surveying*, including *Gravity* work. It was determined to invite a report from the Astronomer Royal, the Director of the Ordnance Survey, and Major Hills, R.E., acting in concert and with power to ask assistance from others. They were further requested specially to consider the past and future relations to such work of the International Geodetic Association.

2. *Meteorology*. It was determined to invite a report from Sir W. N. Shaw, asking him specially to consider the relation of the International Meteorological Council to the work.

3. *Magnetic Observations*. It was determined to invite a report from Dr. Chree, asking him specially to consider the relation of the work of the Carnegie Institution to other work.

4. *Tidal Observations and Currents*. It was determined to invite a report from Professor Lamb.

5. *Seismology*. It was determined to invite a report from Dr. G. W. Walker.

The following Reports have been received:—

1. *Report on Terrestrial Magnetism*. *By* C. CHREE, *D.Sc.*, *F.R.S.* (See Report, 1917, p. 14.)

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2. *Preliminary Report on Tides and Currents*. *By* Professor H. LAMB, *F.R.S.*, and J. PROUDMAN. (See Report, 1918, p. 15.)

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3. *Report of Geodetic Committee, February* 1918.

1. The Geodetic Committee, having been desired to reconsider their proposals for a Geodetic Institute in the light of the needs of Tidal Phenomena, Seismology, and Terrestrial Magnetism, as well as Geodesy, have reviewed the whole question.

2. Evidence has been laid before the Committee of the present position in the Empire of each of these branches of Geophysical Science, of the provision for dealing with them, and of the shortcomings of existing arrangements.

Careful consideration of the evidence submitted has shown that the needs of Geodesy are to a large extent similar to those of the other subjects, and that the following general summary is applicable to Geodesy, Tidal Phenomena, Seismology, and Terrestrial Magnetism.

General Summary.

(*a*) There is no provision for the collection and critical discussion of the work which is being done within the Empire or for its comparison with that which is being done in other countries.

(*b*) The various State Departments and local authorities have no British institution to which they can refer for the latest and most accurate technical data, for the methods which have been found most effective in various circumstances in the Dominions, Colonies, Protectorates, or foreign countries, or the improvements that have been made in instruments, or for the latest advances in the theoretical fields of these subjects, except imperfectly in the case of Terrestrial Magnetism.

(*c*) There is no institution where those who have devoted themselves to these geophysical sciences can still further improve their knowledge of them, investigate the problems that arise, and have at their disposal all the necessary material and instrumental equipment to carry out research work.

Geodesy.

3. The position of Geodesy and its special needs may be stated as follows:—

Besides providing the data from which the true form and dimensions of the earth may be determined—from which, also, can be derived information as to its local irregularities and attractions, its crustal stability and structure—triangulation and levelling, of the degree of precision which geodetic investigations require, provide the most economical basis of work wherever large areas of country have to be surveyed and the boundaries of property defined. They not only provide a reliable control for all other surveying, but also materially raise the standard of accuracy of such work; and, even where second-order surveys are at first employed, work of a geodetic standard must sooner or later be introduced.

Geodetic triangulation and precise levelling are, or have been, in progress in the United Kingdom, India, Egypt, and in Australia, New Zealand, Canada, and South Africa; while work of a similar character will become necessary to a greater or less extent in most of the Crown Colonies and Protectorates as their development proceeds.

Determinations of gravity have been made in the United Kingdom, Egypt, and at numerous coast stations, and form part of the regular work of the Survey of India and are desirable in other parts of the Empire.

Geodetic work must form the basis of the control of all the State Surveys of the Empire, on which about a million sterling was being spent annually before the war.

An institution in which the results of such work in all parts of the Empire would be systematically collected and reviewed, where the methods and instruments were discussed, and where the corresponding work of other nations would be regularly brought into relation with it, would be of great value to all these State Surveys.

Tides.

4. The navigational applications of tidal phenomena are provided for by the Hydrographical Department of the Navy, but there is a part of the subject which is closely related to Geodesy and especially to precise levelling.

Oceanic tide gauges are maintained in the United Kingdom (3), India (9), Canada (4), New Zealand (2), and Australia (1), and their data, which are utilised for providing tide-tables, are valuable also in discussions of sea-level, reference data, and the movements of the crust of the earth. The work of correlating these observations in different countries could be very suitably undertaken in an institution devoted to Geodesy and allied subjects.

Seismology.

5. While there are nine places in the Empire where seismographs exist capable of furnishing data for the determination of the physical properties of the earth, there is a widely spread network of stations equipped with a simpler form of seismograph, which was instituted and developed by the late Professor J. Milne, F.R.S. These stations are situated in all parts of the Empire and also in some foreign countries. During Professor Milne's lifetime he received and discussed the records of all these stations, and practically maintained a Seismological Institute, so far as these instruments were concerned, in the Isle of Wight. Since his death the work has been carried on by the Committee of the British Association, of which he was formerly Secretary.

6. It seems to the Committee that there are two classes of requirements to be considered:—

(1) The need for a few first-class seismological stations, equipped with the best type of seismographs and established in different parts of the Empire, to record the vibrations caused by earth shocks which affect the earth as a whole; and

(2) The study of earthquake frequency, crustal movement, and local earthquake phenomena generally, which may be studied with simpler forms of instrument and under local arrangements.

In the United Kingdom one first-class station would probably suffice, and this might form part of the Geodetic Institute, since the equipment

is not cumbersome, the material received from the Colonies and Protectorates would not be unmanageable, and the seismological study of the physical structure of the earth is closely allied to the investigations of structural problems by geodetic methods. This Institute would form a centre to which local authorities in the Colonies and Protectorates could turn for advice or assistance.

Such a centre would also communicate with the seismological centres in other parts of the Empire, exchange data, and co-operate in the study of the subject. It would also correspond with the Seismological Institutes of other countries, and actively promote the development of this branch of Geophysics in this country.

Terrestrial Magnetism.

7. There is more adequate national provision for the study of Terrestrial Magnetism than is the case with Seismology, though the requirements of Terrestrial Magnetism are not fully met as yet.

Magnetographs are in operation or are about to be established at:—

Great Britain	Greenwich.	Egypt	Helwan.
	Kew.	Australia	West Australia.‡
	Eskdalemuir.		Melbourne.†
	Stonyhurst.	New Zealand	Christchurch.
India	Dehra Dun.	South Africa	Capetown.‡
	Alibag.		Mauritius.
	Kodaikanal.	Canada	Toronto.
Burma	Toungoo.		Meanook.

† To be moved. ‡ Not yet established.

Magnetic observations at sea are made under the direction of the Hydrographer of the Navy, under whom the Superintendent of Naval Compasses works.

Greenwich Observatory, including the Magnetic Department, is maintained by the Admiralty. Continuous magnetic observations have been taken since 1841, and in recent years new housing and equipment have been provided. The observations are published annually and have been discussed at the Observatory and elsewhere. The magnetic observations made by officers of H.M. ships are received from the Hydrographer of the Navy and are used with others in the preparation at the Observatory of the Admiralty Magnetic Charts.

In the year 1871 the late Mr. John Peter Gassiot conveyed to the Royal Society a sum of £10,000 for the purpose of assisting in carrying on and continuing magnetic and meteorological observations and related physical investigations. The proceeds of this fund, together with the grant in aid made by the Treasury to the Royal Society for Eskdalemuir Observatory, are now administered by a Committee of the Royal Society for the work assigned, in augmentation of the sums at the disposal of the Meteorological Committee of H.M. Treasury.

There is, however, no provision for the collection and discussion of the records obtained by the magnetographs in operation in the Empire, nor for the investigation of various problems in terrestrial magnetism which from time to time arise, nor for the periodical revision of such magnetic surveys as have been or may be made of the United Kingdom,

or of the Colonies and Protectorates, nor for any special investigations that may be necessary.

The Committee are of opinion that these needs might be met if for that purpose the resources of the Meteorological Office, which now directs the Observatories of Kew and Eskdalemuir, and receives through the Royal Society the Government grant which has been referred to, were correspondingly increased.

Conclusions.

8. The Committee conclude therefore:—

(*a*) That a Geophysical Institute providing for the requirements of Geodesy, Tidal Phenomena, and Seismology, as above summarised, is required.

(*b*) That such an Institute would prove to be of great service to the State Surveys of the Empire, in providing a centre for research and for the dissemination of information.

(*c*) For such an Institute to be of value it must possess the good will of the State Surveys, and they should be represented on its governing body.

(*d*) That the Institute should be situated near London, and have access to open ground on which practical operations could be carried out; or, alternatively, should be situated in London, with an experimental station near London.

(*e*) That the Institute should form part of, or be affiliated to, an existing educational establishment.

9. The Committee do not find it possible to draw up any estimate of the initial or annual cost of such an Institute that would be of any substantial value until this question of affiliation has been decided and the possibilities as to accommodation investigated.

Procedure.

10. The Committee do not feel that they themselves can carry the matter much further for the present, and they suggest, for the consideration of the Conjoint Board (to which there might, perhaps, be added, for this purpose, representatives of the Colonial Office and of this Committee), that the Board should, in the first instance, approach the Imperial College of Science and Technology and ascertain whether that Institution would be inclined to consider favourably a proposal to establish a Geophysical Institute as one of its Departments.

Should the reply be in the affirmative, any future steps should, perhaps, be taken by the Governing Body of the Imperial College, who would doubtless consult the Conjoint Board and this Committee.

(NOTE.—The Committee proceeded no further, inasmuch as it was reported that further steps had been taken by the Conjoint Board of Scientific Studies and by the University of Cambridge, and an appeal had been issued by the University for funds to found a professorship of geodynamics and a Geodetic Institute.)

4. *Seismology after the War.* *By* G. W. Walker, *A.R.C.Sc., M.A., F.R.S.*

The lamented death in 1913 of that great pioneer of earthquake investigation, Dr. John Milne, followed only two years later by the untimely demise of Prince Boris Galitzin, left the young art of seismometry poor indeed.

The war now ended has rendered impossible for many years to come those friendly personal relations with German seismologists which some of us valued very highly, and has also given the quietus to the International Association of Seismology.

It is with sadness and diffidence that I agree to the request of the British Association Organising Committee, Section A, to give some outline of my views as to the future of the subject, more especially as the matter is not solely a scientific one, but involves also the question of finance and policy. As to the precise meaning and scope of seismology, different opinions may reasonably be held. I sympathise with the view entertained by some geologists that the name has been appropriated by physicists to a subject that has little to do with earthquakes. That is so, for to the modern seismologist, unless he happens to live in a seismic region, the earthquake is of interest only in so far as it reveals the internal dynamical properties of the earth.

Others hold the view (which I share) that all phenomena revealed by seismographs, such as microseisms, earth tides, and the cognate theoretical problems of the form and distortion of the earth, are properly included in seismology.

It has been my privilege for some years to apply the principles of seismology to the study of small-scale artificial earthquakes, and, although I cannot give details at present, I have the greatest confidence in saying that a rich practical harvest is in promise.

The name ' seismology ' is probably not the best for the wide field of investigation that is possible by means of seismographs. After all, it is really the application of dynamics to the earth, and thus the term ' geodynamics,' recently used by the Cambridge Committee, strikes me as being an eminently suitable one for the subject, and one to which little objection could be taken.

There is perhaps no other subject in which the need for international co-operation and a widespread distribution of observing stations is more clearly evident. This was recognised by Dr. Milne, and it would be a lasting disgrace to this country if the scheme he established were allowed to fall through for want of financial support. Doubtless the scheme requires revision, and the instruments should be brought up to date, while stations which are clearly insufficient or unsuitable might be abandoned or replaced by others.

But this raises the question of what scheme is feasible and efficient and most likely to be generally conducive to progress.

From time to time, largely as the result of individual effort, different branches will attain prominence and they may require special legis-

lation. But among matters which appear to me the most pressing at present are:—

(1) The precise investigation of time curves and earth tides and their interpretation.

(2) Investigations in manifestly seismic regions.

The first is concerned with large-scale uniformities of the earth, and the stations should be in non-seismic regions. The instruments must be of the highest degree of precision as regards sensitiveness and time accuracy, and it is vital that the vertical component, as well as the horizontal components, of motion should be recorded and analysed. I do not think any great improvement in time curves will be obtained without the use of the vertical component. A somewhat analogous case occurs in terrestrial magnetism, where the vertical component is the discriminating factor.

Earth tides are important, among other reasons, because they provide a check on the internal properties of the earth deduced from the time curves.

As regards the number of stations, the more the better, provided they are really efficient. But much could be done by comparatively few stations. Is it too much to suggest that, as a start, England and each of the Dominions—Australia, Canada, India, and South Africa—should provide a fully-equipped first-order station? These might be supplemented as occasion arises in order to fill up lacunæ in the time curves.

For the second investigation more numerous stations are required near the regions selected, but the instruments would not, in general, require to be so sensitive, nor need three components be registered at all the stations. The object of such investigation is to some extent local, and the co-operation of geologists would clearly be fruitful in throwing light on the connection between volcanic action and earthquakes. One thinks of New Zealand as an obvious field for such work.

Such a scheme requires close co-operation between parts (1) and (2) for success, but I can imagine that the first-order station for (1) would in its own region supervise (2)—e.g. Australia and New Zealand or India and the East Indies.

The first-order stations, limited in number, would in turn co-operate with a central body, which I will assume is in England.

This brings one to the question of apparatus and standardisation.

Whatever instruments are used, standardisation is really essential. It involves equipment for determining all the constants of the apparatus and an experimental table by means of which a variety of artificial motions can be given to the instrument and the results observed. The necessity is almost self-evident, and its practical use was fully demonstrated by Prince Galitzin.

The question of instruments is somewhat more difficult, as we may expect these to be modified and improved in course of time.

At present it is recognised that the most precise and most sensitive installation for all three components is Galitzin's system of aperiodic pendulums, with galvanometric registration, and until something better has been devised it would be a good thing if all the first-order stations

were furnished with these. They do not, however, give the earth tides, and, like all other seismographs, they do not give a precise reproduction of the earth movement. This was recognised by Galitzin, and, shortly before his death, he brought out his new apparatus for measuring the acceleration of the ground directly, by using the piezo-electric property of quartz. Whether these instruments will do for continuous seismometry remains to be proved. There are, however, other methods, and there is ample scope for work in this direction.

As the question of instruments is so essential to progress in obtaining records in the simplest form, I may be permitted to add some remarks on a subject so frequently ignored.

In the initial search for a new effect one works rather in the dark, and it is simply a question of getting an effect at all. But when we have obtained some idea of the order of magnitude, and especially of the time element of change, the suitable instrument for measuring it is not a mere accident, but a matter for scientific design.

A seismometer being essentially a pendulum, and the disturbance due to an earthquake a complex phenomenon, the instrument in general gives a record which is neither displacement, velocity, nor acceleration, but a mixture, while some parts of the disturbance are exaggerated relative to others. Strict aperiodicity is a great help, and, in my view, essential. And here may I enter a protest against the frequent application of the term 'dead-beat,' which is really the same as aperiodic (and has a precise quantitative significance), to cases where large damping of indefinite amount is all that is meant?

The primary period of the apparatus is a very important element in an instrumental record, so that an apparatus suitable for giving the long-wave phase of an earthquake may not be so suitable for the first phase.

In conclusion, it appears that there is ample scope in the future for:—

(1) The scientific design of apparatus suitable for recording the various movements of the earth.

(2) The establishment of even a few first-order stations, one in each of the principal countries of the Empire, for recording all three components of motion with a view to a determination of the mechanical properties of the interior of the earth.

(3) The establishment of a larger number of second-order stations for the investigation of local earthquakes.

(4) Theoretical investigation of the form and stability of the crust, and the propagation of wave motion throughout the interior.

Seismological Investigations.—Twenty-third Report of the Committee, consisting of Professor H. H. Turner (*Chairman*), Mr. J. J. Shaw (*Secretary*), Mr. C. Vernon Boys, Dr. J. E. Crombie, Sir Horace Darwin, Dr. C. Davison, Sir F. W. Dyson, Sir R. T. Glazebrook, Professors C. G. Knott *and* H. Lamb, Sir J. Larmor, Professors A. E. H. Love, H. M. Macdonald, J. Perry, *and* H. C. Plummer, Mr. W. E. Plummer, Professors R. A. Sampson *and* A. Schuster, Sir Napier Shaw, Dr. G. T. Walker, *and* Dr. G. W. Walker.

General.

The Committee asks to be reappointed, with a grant of 100*l.* (including printing), in addition to 100*l.* from the Caird Fund already voted. The Government Grant Fund administered by the Royal Society has voted a subsidy of 200*l.* for 1919, as in recent years.

It was hoped that some modification of this application might have been made this year. Under the auspices of the International Research Council, which met at Brussels July 18-28, a Geodetic and Geophysical Union was constituted, with Seismology as one of its sections. This involves ultimately the establishment of a Seismological Bureau or Central Office, where different records may be collated and discussed, and experimental and standardisation work carried out; and in view of all the circumstances (including the death of Prince Galitzin and the uncertain future of seismology in Russia, the interruption of relations with Germany, and the previous history of seismology in the British Empire) it was hoped that some locality in England, and probably Oxford, might be chosen as the locality for the Bureau.

In anticipation of the Brussels meeting a National Research Council for Geophysics had been constituted under the auspices of the Royal Society, and at the meeting of this Council on June 20 the following resolution was adopted, on the motion of Professor Schuster:—

> 'That an offer be made to the Section of Seismology of the International Union of Geodesy and Geophysics to locate its Central Bureau at Oxford; but that the Executive Committee of the Section have power to transfer it to another locality in Great Britain on the recommendation of the National Research Council for Geophysics in that country.'

When, however, the location of the Central Bureau came up for preliminary discussion at Brussels, it was found that the French were anxious that the claims of Strasbourg, now so dramatically restored to them, should be considered. As a possible way of meeting both wishes, a division of the work of the Bureau between Strasbourg and Oxford was suggested; but at this point it was remarked that there were still some points to be settled in connection with the formerly existing International Seismological Association, and ultimately it was decided to defer the formation of the Seismological Section until these

points had been finally disposed of, for there was a general agreement that a totally new departure, untrammelled by links with the past, was desirable at this juncture. Hence no definite steps towards the formation of a Seismological Section were taken at Brussels, and the work of the Committee will proceed as nearly as possible on the same lines as before for the next year or two.

But an important change of locality has become inevitable. On the approach of Peace, Mrs. Milne decided to return to Japan as soon as her voyage could be arranged. This involved the sale of the house at Shide to which the Milne Observatory (partly a disused stable, partly an office specially built) is attached, and it was not feasible to continue the use of the observatory under these conditions. As a provisional measure the instruments and apparatus are being transferred to Oxford, where a Milne-Shaw machine had already been set up (see last Report), and where the facilities temporarily accorded by Mr. James Walker have been kindly continued by the newly appointed Professor (Dr. F. A. Lindemann). At the moment of writing this transference is not complete, and a fuller account of it is deferred to the next report.

Instrumental.

Wireless time signals were received at Shide regularly up to the time of removal of the seismographs. The transit lent by the Royal Astronomical Society has been returned.

The wireless receiving apparatus which had been installed at Oxford before the War, but taken down on the commencement of hostilities, was again set up last autumn, and signals have been regularly received.

Milne-Shaw Seismographs.

One of these was set up in the Clarendon basement at Oxford by Mr. J. J. Shaw on October 8, 1918, just in time to catch the big earthquake of October 10. Others are completed, or nearly completed, but it will be convenient to defer details of their installation to the next report. One of them has been installed by Mr. J. J. Shaw for trial in a 'dug-out' at some distance from his house at West Bromwich, and some interesting results obtained. But of these again details are deferred. The past year, owing to the cessation of hostilities, has brought with it so many needs and distractions that this report is necessarily somewhat imperfect.

Suggested Corrections to Adopted Tables.

This work is proceeding. The suggested corrections are being applied provisionally to obtain new determinations of epicentres in the cases of well-observed earthquakes. This second approximation should show how far the corrections are valid. The work is, however, somewhat extensive, and no report can be profitably made as yet.

Earthquake Periodicity.

In the 1912 Report of this Committee evidence was given for the existence of a periodicity of nearly 15 months (there identified as

104/7 months) deducted from the *Catalogue of Destructive Earthquakes* compiled under Milne's superintendence. It was natural to examine the independent *Catalogue of Chinese Earthquakes* compiled by Milne's Japanese assistant, Shinobu Hirota, and published in the 1908 Report of this Committee (Section XI.), with additions by Professor E. H. Parker in the 1909 Report (Section XII.). The result was to confirm the periodicity and to define it more exactly as of period 451·805 days= 14·8438 months=1·2370 years. The investigation is given in the Monthly Notices R.A.S., lxxix., p. 461, and it is pointed out that the periodicity seems to be affected by one of long period (about 78 years). This led to the examination of the same Chinese series for long periods (see *Mon. Not. R.A.S.* lxxix., p. 531), of which several seem to be worth further investigation. The most notable is not the one above mentioned (78 years), but one of about 240 years (which may therefore be 3×78 years), which is conspicuous in the Chinese earthquakes and was also found in the records of Nile flood. It is, however, only faintly traceable in Milne's *Catalogue of Destructive Earthquakes*, and the question arises how far the heterogeneous nature of the latter can be held responsible for the loss of this periodicity, and how far, on the other hand, the Chinese records can be regarded as possessing the necessary homogeneity. There is no doubt of the defective nature of the material in the *Destructive Earthquakes* in the early centuries. The increase in volume of the records is so considerable as quite possibly to overwhelm any signs of periodicity. For example, let us limit attention to European earthquakes and to those marked III. by Milne (*i.e.*, as 'having destroyed towns and devastated districts'). It might be supposed that these would be recorded with some approach to completeness, yet the numbers for successive periods of 180 years are as shown:—

AD 631 — 811	— 991	— 1171	— 1351	— 1531	— 1711	— 1891
11	9	14	22	19	39	117

Unless there has been an improbable increase in the number of such quakes, the figures for 1711–1891 show that only about one in ten was recorded in earlier centuries. If this happens for European records, others will scarcely be in better case, and when we compound the different sources it is perhaps not surprising if the accidental errors are large enough to mask periodic phenomena.

The Chinese records are also probably far from complete, but they have an appearance of much greater steadiness of some kind, which may quite possibly be real. A critical discussion by Chinese scholars would be of great interest.

Meanwhile we turn to some numerical relations among the periodicities indicated, which seem to strengthen the evidence for their reality.

Firstly, remark that the period of 451·805 days (or 1·2370 years) is sensibly different from that found for the movements of the earth's axis from astronomical observations. The most recent discussion of this latter period by Sir F. W. Dyson (*Mon. Not. R.A.S.*, lxxviii., p. 452) gives it as about 432 days, or accurately 7·10/6 years= 1·1833 years. Neither determination can be so much in error as

20 days. We must apparently recognise two distinct periodicities connected in some way with our earth, and our attention is naturally directed to possibilities of interference.

Now $21 \times 1{\cdot}23698$ years $= 25{\cdot}97658$ years.
$22 \times 1{\cdot}18333$ years $= 26{\cdot}03333$ years.

So that the two periodicities interfere in approximately 26 years. But the differences from 26 years are by no means negligible. If we adopted exactly 26/21 years for the former we should be returning to the period of 104/7 months tentatively deduced from the *Catalogue of Destructive Earthquakes* and shown by the *Chinese Earthquakes* to be in error by about one month in 78 years. The length of the Chinese series warrants our retaining 5 significant figures.

The astronomical determination, though deduced from observations of a much higher order of accuracy, depends on a much shorter series, and the number of significant figures is fewer. Dyson contents himself with 3, and if we vary his last figure by a few units we get:—

$22 \times 7{\cdot}08/6 = 22 \times 1{\cdot}18000 = 25{\cdot}9600$
$22 \times 7{\cdot}09/6 = 22 \times 1{\cdot}18167 = 25{\cdot}9967$
$22 \times 7{\cdot}10/6 = 22 \times 1{\cdot}18333 = 26{\cdot}0333$
$22 \times 7{\cdot}11/6 = 22 \times 1{\cdot}18500 = 26{\cdot}0700$

In the first case interference with the earthquake period would take place in rather less than 26 years, in the other cases in rather more. To put the point in another way, let us calculate the period of the earth's axis which would interfere with that deduced from earthquakes (supposed accurate) in various assigned times, say 25 years, 26 years, and 27 years.

Period of Interference	Period of Earth's Axis	Six times
	years	years
25 years	1·1784	7·070
26 years	1·1805	7·083
27 years	1·1825	7·095

It will be seen that if this period of interference could in any way be independently identified we might deduce a close value for the period of the earth's axis.

Now, although this actual period has not as yet presented itself in other connections, its multiples, and perhaps its submultiples, have so presented themselves several times over.

Thus we have:—

3×26 years $= 78$ years
6×26 years $= 156$ years
9×26 years $= 234$ years

The last may possibly be the 240-year period already mentioned as conspicuous in the Chinese earthquakes (*Mon. Not.* lxxix., p. 531) in the Nile floods, and possibly in the motion of the moon. A period of 156 years approximately was found by Mr. A. E. Douglass in the growth of trees (*Bull. Amer. Geog. Soc.* xlvi., pp. 321-335, 1914), and is illustrated by a striking diagram in Professor D'Arcy Thompson's

book on *Growth and Form*, p. 122 (Camb. Univ. Press, 1917). The actual length is apparently shorter than 156 years—nearer 150 years, but the material is scarcely sufficient to warrant a very precise estimate. The Chinese earthquakes show this periodicity of 156 years very clearly. Dividing the period into 18 equal parts the totals are as in the columns O, the columns C being calculated from the formula:—

$$C = 45 + 15{\cdot}6 \text{ Cos } (O - 225°).$$

Period of 156 *years in Chinese Earthquakes, exhibited in* 18 *groups of* 7 *years.*

O	C	O−C	O	C	O−C	O	C	O−C
29	34	− 5	30	41	−11	59	61	− 2
38	31	+ 7	32	46	−14	54	68	−14
32	30	+ 2	40	51	−11	63	54	+ 9
56	29	+27	69	56	+13	41	49	− 8
30	32	− 2	70	59	+11	32	44	−12
29	36	− 7	66	60	+ 6	35	39	− 4

The differences O—C show a variation in the half-cycle of 78 years, to which attention has already been drawn in the paper on the 15-month period (*loc. cit.*), and, moreover, the phases of the 15-month term vary in this half-cycle of 78 years and in the quarter-cycle of 39 years. This quarter-cycle appears in numerous meteorological phenomena, and should probably replace the supposed 'Brückner Cycle' of 35 years (see *Q.J.R. Met. Soc.* xli., p. 322).

But 39 years is no longer a multiple of 26 years, though related to it. The submultiple of both—*viz.*, 13 years—has, however, been shown to affect a large number of meteorological phenomena, being a double 'chapter' of the kind indicated in the paper just cited, and others which have followed it.

As yet it cannot be said that we have anything really tangible in the shape of a physical hypothesis, but these numerical relations are certainly suggestive, and are sufficient to guide further inquiry. Naturally in tentative exploration of this kind much time is spent in unproductive essays, but this need not be grudged.

Radiotelegraphic Investigations.—Report of the Committee, consisting of Sir OLIVER LODGE (*Chairman*), Dr. W. H. ECCLES (*Secretary*), Mr. S. G. BROWN, Dr. C. CHREE, Sir F. W. DYSON, Professor A. S. EDDINGTON, Dr. ERSKINE-MURRAY, Professors J. A. FLEMING, G. W. O. HOWE, H. M. MACDONALD, *and* J. W. NICHOLSON, Sir H. NORMAN, Captain H. R. SANKEY, Professor A. SCHUSTER, Sir NAPIER SHAW, *and* Professor H. H. TURNER.

DURING the past twelve months the war-time restrictions on wireless telegraphy have continued in operation. A few statistical records from British Colonial Radio Stations have been sent regularly to the Committee, and occasional information from other parts of the world has been received.

Solar Eclipse of May 29.

In connection with the solar eclipse of May 29 the Committee arranged for the carrying out of experiments on the effect of the eclipse on signals transmitted across the central line. The British Admiralty stations at Ascension and the Azores transmitted continuously during the transit of the umbra across the Atlantic Ocean. Observing stations north of the equator were for the most part asked to listen to Ascension for at least an hour round about the time when the umbra passed between themselves and Ascension; observers south of the equator were asked for the most part to listen to the Azores. Certain selected stations north of the equator were asked to listen to the Azores, so as to afford check observations upon the variations which might be observed in signals passing across the central line of the eclipse, and, similarly, selected stations south of the central line were asked to listen to Ascension. The American station at Sayville also transmitted a programme during a portion of the period of the eclipse, and arrangements were made for special experiments between Darien and the Falklands, and between an Egyptian station and a South African station.

The main portion of the experiment hinged upon Ascension. The umbral cone passed from West to East, and was expected to affect in succession the strength in which signals were received at such stations as Demerara, Jamaica, the stations on the coast of the United States and Canada, stations in Ireland, England, France, Italy, in the Mediterranean and Egypt.

The shadow of the moon struck the earth first at dawn on the coast of South America and swept across the Continent in the course of half an hour, at first with enormous velocity, but losing speed as the Atlantic Ocean was approached. About the middle of the Atlantic Ocean and near the equator the speed of the shadow was about one-third of a mile per second. On crossing the African Continent from the Gulf of Guinea to the Mozambique Channel the speed gradually increased, and

the eclipse finished at sunset near Madagascar. The effects of the moving shadow were investigated under three heads:—

(1) Strays.
(2) Signals not crossing the denser parts of the shadow.
(3) Signals crossing through or near the umbra.

Strays.

These were bad on the day of the eclipse and on the preceding day in Europe, North America, and in temperate latitudes on the Atlantic Ocean. They were very few in Central and South America and in the central equatorial Atlantic. In Central America the conditions were exceptional meteorologically, the day having less rain than nearly every day of the preceding three weeks. The preliminary survey of the results recorded throughout the part of the globe reaching from Constantinople to Rio Janeiro suggests that there was no outstanding occurrence in regard to frequency or intensity of strays that could be directly ascribed to the passage of the shadow.

Signals not traversing the dense shadow.

Many observations were made in Northern Europe and America on the signals from the Azores, which were arc signals of 4,700 metres wave-length. The observing points extended from Berlin through Holland, France, Italy, Spain, and Great Britain to stations near the Atlantic coast of the United States. There were no unusual variations in the strength of the signals from the Azores.

Another class of experiment comes under this heading. It was suggested by the effect sometimes observed at sunset or sunrise, in which the twilight band when on one side of a transmitting station appears to strengthen as if by reflection the waves received at a station on the other side of the transmitting station. In order to test whether such reflections occurred during an eclipse certain stations on the south of the central line of the eclipse were asked to listen to Ascension, which was also south of the central line. The stations at Durban and Port Nolloth (South-West Africa) found no trace of the effect, and in fact the former concluded that the signals from Ascension were rather worse after the eclipse began. An analogous experiment on the northern side was carried out by one of the Malta stations and also at Rosyth, listening to Cairo, with similar conclusions.

Effect on Signals passing across the Central Line.

Arrangements were made for the transmission of signals from the Darien station of the Panama Canal zone, and several stations in South America attempted to receive the signals. The report from the Falkland Islands has not yet come to hand, and the other stations in South America did not succeed in picking up the signals. The only observation made on the earlier stages of the eclipse are those of Demerara listening to Ascension. Fluctuations in signal strength are reported, but no steady increase or decrease in strength. Ships at sea within the penumbra report a strengthening of all signals during the eclipse.

The most striking results were obtained at some of the stations in France, Malta, and Teneriffe. At Meudon and at Roussillon the signals from Ascension were received practically only while the eclipse was in progress. Both Malta and Teneriffe found that the eclipse produced a great improvement in the strength of signals. On the other hand, Durban was unable to pick up Cairo, though this is usually possible, but Aden was picked up with greater intensity than normal. On the whole, the records show that the improvement in signal strength reached its highest value long before the umbra intervened between the stations, and this value persisted after the umbra had passed; that is to say, if ionising processes are the cause of the change in the strength of signals, the results indicate that the processes are practically fully accomplished in a given region of the air before the arrival of the umbra at that place, so that there appears to be nothing left for the umbra to do in the few minutes of complete shadow it brings.

The thanks of the Committee are due especially to the Admiralty for arranging that their stations at Ascension and the Azores should transmit the necessary signals, and also to the American Government for making similar arrangements regarding Sayville and Darien. Thanks are due also to the American, French, and Italian Governments, the Admiralty, the War Office, the Air Ministry, and Marconi's Wireless Telegraph Co., Ltd., for undertaking observations and recording the variations in signal strength.

The Calculation of Mathematical Tables.—Report of the Committee, consisting of Professor M. J. M. Hill (*Chairman*), Professor J. W. Nicholson (*Secretary*), Dr. J. R. Airey, Mr. T. W. Chaundy, Professor L. N. G. Filon, Sir G. Greenhill, Professor E. W. Hobson, Mr. G. Kennedy, *and* Professors Alfred Lodge, A. E. H. Love, H. M. Macdonald, G. B. Mathews, G. N. Watson, *and* A. G. Webster.

Report on Mathematical Tables of the Elliptic Function.

Criticism was invited of the arrangement of the system proposed of tabulation, and of the accuracy of the tables calculated as specimens, in the Reports 1911, 1912, 1913, on the Elliptic Function.

Some fault was found with the final decimals in the table of the Lemniscate Function $K=K'$, $\theta=45°$, p. 50, Report 1912.

As this table has been used as the base of the calculation of the table for

$$K=(2, 3, 4, 5, 7, \ldots .)\ K',$$

by means of a transformation of the order 2, 3, 4, ... as explained, p. 88, Report 1913, it was decided to make a recalculation to a higher accuracy, going to 10 decimals.

This was undertaken by Colonel R. L. Hippisley, and is given here in Table I, with a description of the formulas of the series employed; and also of the independent verification by the division values, trisection, quinquisection, and others, given by expressions of finite form.

The notation proposed in Report 1911 may be recalled here, of the six functions tabulated, A, B, C, D, E, F, with $r=90f$,

$$D(r)=\frac{\Theta fK}{\Theta 0}, \quad A(r)=\frac{HfK}{HK};$$

$$C(r)=D(90-r)=\frac{\Theta(1-f)K}{\Theta 0}, \quad B(r)=A(90-r)=\frac{H(1-f)K}{HK},$$

in terms of the theta and eta function of Jacobi.

The elliptic functions are then given by

$$\sqrt{\kappa'}\ \mathrm{sn}fK=\frac{A(r)}{D(r)}, \quad \mathrm{cn}fK=\frac{B(r)}{D(r)},$$

$$\sqrt{\kappa'}\ \mathrm{tn}fK=\frac{A(r)}{B(r)}, \quad \frac{\mathrm{dn}fK}{\sqrt{\kappa'}}=\frac{C(r)}{D(r)}.$$

Jacobi's zeta function is given by

$$\mathrm{zn}fK=E(r), \quad \mathrm{zn}(1-f)K=F(r)=E(90-r).$$

The table runs down to $r=45$, and then up again to $r=90$, as in the ordinary circular function.

A connexion is made with the original Table IX of Legendre, for $F\phi$ in terms of ϕ, by the two outside columns; of ϕ and ψ, given in degrees, where

$$\phi=\text{am } f\text{K}, \qquad F\phi=f\text{K}=\frac{r}{90}\text{K},$$

$$\psi=\text{am } (1-f)\text{K}, \qquad F\psi=(1-f)\text{K}=\frac{90-r}{90}\text{K},$$

proceeding by equal increments of r and f, whereas Legendre's Table IX takes equal steps in ϕ.

The basis on which these three tables have been calculated is the value of $e^{-\pi}$ which Gauss has given to 51 places of decimals (Werke, vol. iii., p. 426). This is the value of q for the modulus $\frac{1}{\sqrt{2}}$, when $\text{K}=\text{K}'$ and $\theta=45°$. The various powers of q, integral and fractional, required for the q series were calculated to 20 places by the aid of an arithmometer, kindly lent for the purpose by Dr. Western, and are collected in the accompanying table.

In the case of the lemniscate functions ($\text{K}=\text{K}'$) all the entries were computed by means of the q formulæ,

$$\Theta u=1-2q\cos 2x+2q^4\cos 4x-2q^9\cos 6x+\ \ldots,$$

$$\text{H}u=2q^{\frac{1}{4}}\sin x-2q^{\frac{9}{4}}\sin 3x+2q^{\frac{25}{4}}\sin 5x-\ \ldots,$$

$$Zu=\frac{2\pi}{\text{K}}\sum_1^\infty[\sin 2nx(q^n+q^{3n}+q^{5n}+\ \ldots)],$$

$$\text{E}(r)=\text{zn}f\text{K}=\frac{\pi}{\kappa}\sum\frac{\sin nr°}{\text{sh } n\pi},$$

where $u=f\text{K}$, $x=\frac{1}{2}\pi f$, $\sin nx=\sin nr°$, $\cos 2nx=\cos 2nr°$.

The tables for $\text{K}=2\text{K}'$ and $\text{K}=4\text{K}'$ have been determined by transformation from the Lemniscate Functions, according to the formulæ given by Sir George Greenhill in Report iii. 1913 of the British Association Committee on Mathematical Tables.

The q formulæ for the higher values of the modulus, especially that for Zu, are very slowly convergent. From 35 to 40 terms in the series for Zu would be required for each entry in the table for $\text{K}=4\text{K}'$ to ensure an accuracy of ten significant figures. Check values for $r=15$, 30, 45, 60, 75 have, however, been obtained by the q formulæ, and all the tables have been submitted to scrutiny by the method of differences to the fifth and sixth orders.

The values of K have been obtained from the formula

$$\text{K}=\frac{\pi}{2\kappa'}\Theta 0^2,$$

and E′ from

$$\text{E}'=\frac{\pi}{2}\left[1-\sum_1^\infty\left(\frac{1.3.5\ldots 2r-1}{2.4.6\ldots 2r}\right)^2\frac{\kappa'^{2r}}{2r-1}\right]$$

but E, for which the above series is slowly convergent, has been calculated from

$$\text{E}\text{K}'+\text{E}'\text{K}-\text{K}\text{K}'=\tfrac{1}{2}\pi.$$

The Lemniscate Function.

1. This is the name given to the elliptic function when the modular angle $\theta=45°$, and $K=K'=L$.

It arises in the Weierstrass form when $g_3=0$ in $S=4s^3-g_2s-g_3$; and then taking $g_2=1$, $\Delta=1$, $\omega_1=\omega_3=L$, and the period parallelogram is a square; and $s_1=\frac{1}{2}$, $s_2=0$, $s_3=-\frac{1}{2}$.

Some writers prefer $s_1=1$, $s_2=0$, $s_3=-1$, $g_2=4$, $\Delta=64$, but this has the disadvantage of making

$$\omega_1=\omega_3=\frac{L}{\sqrt{2}}=1{\cdot}3110287771460598\ldots$$

which is Stirling's A, given in Halphen's *Fonctions elliptiques*, I., p. 64.

But with $g_2=1, g_3=0$, $S=4s^3-s$,

$$(1)\qquad L=\int_{\frac{1}{2},\,-\frac{1}{2}}^{\infty,\,0}\frac{ds}{\sqrt{S}}=\int_{0,\,-\infty}^{\frac{1}{2},\,-\frac{1}{2}}\frac{ds}{\sqrt{-S}}=1.8540746773,$$

the number employed by Legendre, Jacobi, and all subsequent writers.

In the general case, with S resolved into real factors,

$$(2)\qquad S=4s^3-g_2s-g_3=4\,.\,s-s_1\,.\,s-s_2\,.\,s-s_3,\quad s_1>s_2>s_3,$$

$$(3)\quad \kappa^2=\frac{s_2-s_3}{s_1-s_3},\ \kappa'^2=\frac{s_1-s_2}{s_1-s_3},\ K=\int_{s_1,\,s_3}^{\infty,\,s_2}\frac{\sqrt{(s_1-s_2)}ds}{\sqrt{S}},\ K'=\int_{s_2,\,-\infty}^{s_1,\,s_3}\frac{\sqrt{(s_1-s_3)}ds}{\sqrt{(-S)}},$$

and the first elliptic integral will be expressible by the inverse elliptic function of Jacobi, in one of the forms

$$(4)\quad \infty>s>s_1,\ eK=\int_{s}^{\infty}\frac{\sqrt{(s_1-s_3)}ds}{\sqrt{S}}=$$

$$\mathrm{sn}^{-1}\sqrt{\frac{s_1-s_3}{s-s_3}}=\mathrm{cn}^{-1}\sqrt{\frac{s-s_1}{s-s_3}}=\mathrm{dn}^{-1}\sqrt{\frac{s-s_2}{s-s_3}},$$

$$(1-e)K=\int_{s_1}^{s}\quad ,,\quad =$$

$$\mathrm{sn}^{-1}\sqrt{\frac{s-s_1}{s-s_2}}=\mathrm{cn}^{-1}\sqrt{\frac{s_1-s_2}{s-s_2}}=\mathrm{dn}^{-1}\sqrt{\frac{s_1-s_2\,.\,s-s_3}{s_1-s_3\,.\,s-s_2}},$$

$$(5)\quad s_1>s>s_2,\ fK'=\int_{s}^{s_1}\frac{\sqrt{(s_1-s_3)}ds}{\sqrt{(-S)}}=$$

$$\mathrm{sn}^{-1}\sqrt{\frac{s_1-s}{s_1-s_2}}=\mathrm{cn}^{-1}\sqrt{\frac{s-s_2}{s_1-s_2}}=\mathrm{dn}^{-1}\sqrt{\frac{s-s_3}{s_1-s_3}},$$

$$(1-f)K'=\int_{s_2}^{s}\quad ,,\quad =$$

$$\mathrm{sn}^{-1}\sqrt{\frac{s_1-s_3\,.\,s-s_2}{s_1-s_2\,.\,s-s_3}}=\mathrm{cn}^{-1}\sqrt{\frac{s_2-s_3\,.\,s_1-s}{s_1-s_2\,.\,s\ -s_3}}=\mathrm{dn}^{-1}\sqrt{\frac{s_2-s_3}{s-s_3}},$$

$$(6)\quad s_2>s>s_3,\ (1-e)\mathrm{K}=\int_s^{s_2}\frac{\sqrt{(s_1-s_3)}ds}{\sqrt{\mathrm{S}}}=$$

$$\mathrm{sn}^{-1}\sqrt{\frac{s_1-s_3\,.\,s_2-s}{s_2-s_3\,.\,s_1-s}}=\mathrm{cn}^{-1}\sqrt{\frac{s_1-s_2\,.\,s-s_3}{s_2-s_3\,.\,s_1-s}}=\mathrm{dn}^{-1}\sqrt{\frac{s_1-s_2}{s_1-s}},$$

$$e\mathrm{K}=\int_{s_2}^{s}\quad,,\quad=$$

$$\mathrm{sn}^{-1}\sqrt{\frac{s-s_2}{s_2-s_3}}=\mathrm{cn}^{-1}\sqrt{\frac{s_2-s}{s_2-s_3}}=\mathrm{dn}^{-1}\sqrt{\frac{s_1-s}{s_1-s_2}},$$

$$(7)\quad s_3>s>\infty,\ (1-f)\mathrm{K}'=\int_s^{s_3}\frac{\sqrt{(s_1-s_3)}ds}{\sqrt{(-\mathrm{S})}}=$$

$$\mathrm{sn}^{-1}\sqrt{\frac{s_3-s}{s_2-s}}=\mathrm{cn}^{-1}\sqrt{\frac{s_2-s_3}{s_2-s}}=\mathrm{dn}^{-1}\sqrt{\frac{s_2-s_3\,.\,s_1-s}{s_1-s_3\,.\,s_2-s}},$$

$$f\mathrm{K}'=\int_{-\infty}^{s}\quad,,\quad=$$

$$\mathrm{sn}^{-1}\sqrt{\frac{s_1-s_3}{s_1-s}}=\mathrm{cn}^{-1}\sqrt{\frac{s_3-s}{s_1-s}}=\mathrm{dn}^{-1}\sqrt{\frac{s_2-s}{s_1-s}}.$$

In the special lemniscate case, where $g_3=0$, $g_2=1$,

$$\kappa^2=\kappa'^2=\tfrac{1}{2},\ s_1=\tfrac{1}{2},\ s_2=0,\ s_3=-\tfrac{1}{2},\ \sqrt{(s_1-s_3)}=1,\ \mathrm{K}=\mathrm{K}'=\mathrm{L}.$$

The name arose historically in the rectification of the lemniscate

$$(8)\qquad r^2=2a^2\cos 2\theta,$$

$$(9)\qquad \frac{dr}{rd\theta}=-\tan 2\theta,\ \frac{ds^2}{d\theta^2}=r^2\sec^2 2\theta=2a^2\sec 2\theta,$$

$$(10)\qquad \frac{s}{a}=\int_0^{\theta}\frac{d\theta}{\sqrt{(\frac{1}{2}\cos 2\theta)}},\ \text{for the arc AP}=s.$$

Then putting $\cos 2\theta=\cos^2\phi$,

$$(11)\qquad \frac{s}{a}=\int\frac{d\phi}{\sqrt{(\frac{1}{2}\,.\,1+\cos^2\phi)}}=\int\frac{d\phi}{\sqrt{(1-\frac{1}{2}\sin^2\phi)}}=F(\phi,\ \sin 45^\circ)=e\mathrm{L},$$

and writing cl for cn, ..., to represent the lemniscate function,

$$(12)\qquad \cos\phi=\mathrm{cl}\ e\mathrm{L}=\mathrm{cl}\frac{s}{a},\ \cos 2\theta=\mathrm{cl}^2 e\mathrm{L},\ \cos\theta=\mathrm{dl}\ e\mathrm{L},$$

$$\tan\theta=\mathrm{cl}(1-e)\mathrm{L};$$

and so the cn, cl function is the first in importance compared with sn, dn, or sl, dl.

With $\cos 2\theta = \frac{r}{2a^2} = z^2$ as variable in the integral,

$$\frac{s}{a} = e\mathrm{L} = \int^{1} \frac{dz}{\sqrt{(\frac{1}{2} \cdot 1 - z^4)}} = \mathrm{cl}^{-1} z \; ; \tag{13}$$

but

$$\int_{1} \frac{dz}{\sqrt{(\frac{1}{2} \cdot z^4 - 1)}} = \mathrm{cl}^{-1} z, \tag{14}$$

obtained from the Weierstrass form by putting $s = \frac{1}{2} z^2$.

The lemniscate can be described by means of a three-bar linkage, where the rotating links FG, F′G′ in the figure are equal, and the traversing link GG′ and fixed link FF′ are each $\sqrt{2}$ times the length of a rotating link.

The mid-point P of the traversing link will then describe the lemniscate curve.

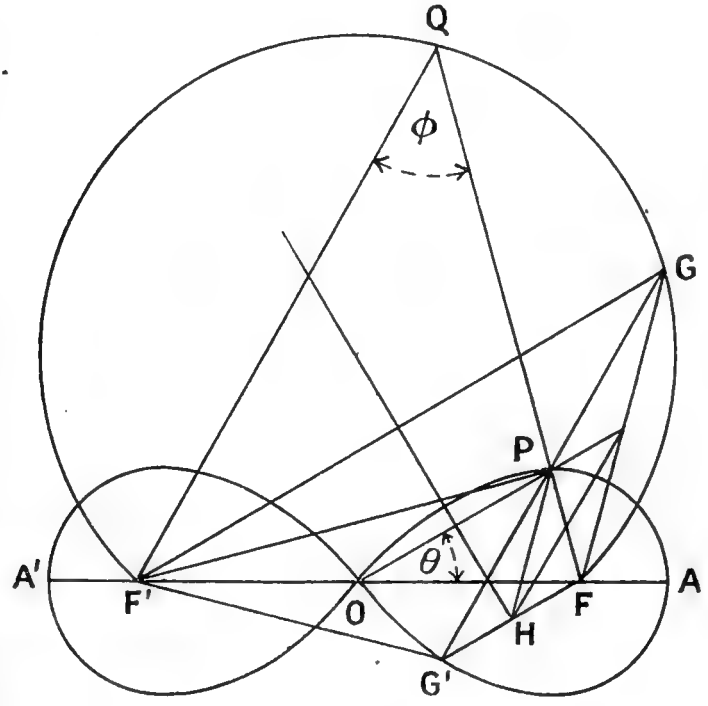


FIG. 1.

Lemniscate APO.

OF = OF′ = 25 mm.
OA = OA′ = 35 mm. = FG = F′G′.
GG′ = 50 mm.
GP = PG′ = 25 mm.
AOP = 30° = θ.
FAF′ = FGF = 45°.

Produce FP to meet the circle round FG, F′G′ in Q. Then, since $FG^2=2GP^2=GP.GG'$, the circle round FPG′ touches FG; QF′G=QFG=GG′F=G′GF′, so that F′Q is parallel to GG′, and PF′=PQ. Then $FP.PF'=FP.FQ=GP.PG'=a^2$, if GP=OF=a, FG=F′G′=$a\sqrt{2}$, FF′=GG′=2a. This is the property of the lemniscate, leading to the polar equation $r^2=2a^2\cos 2\theta$, with OP=r, AOP=θ, FQF′=FGF′=ϕ, FG sin ϕ=FF′ sin θ, $\sin^2\phi=2\sin^2\theta$, $\cos^2\phi=\cos 2\theta$,

$$r=\mathrm{OP}=2\mathrm{PH}\cos\phi=\mathrm{FG}\cos\phi,\ r^2=2a^2\cos^2\phi=2a^2\cos^2\theta.$$

The rectification of the lemniscate may be considered to have originated the true theory of the Elliptic Function in that it introduced the First Elliptic Integral, inverse of the uniform Elliptic Function.

The previous efforts at the rectification of the Ellipse, which gave the name to the Elliptic Integral, were on the wrong track, as leading to the Second Elliptic Integral, not the inverse of a uniform function.

The lemniscate can be expressed in the vector form, in terms of a parameter u,

$$(15)\qquad x+iy=a\ \mathrm{sech}(u+\tfrac{1}{4}\pi i),\ r^2=2a^2\ \mathrm{sech}\ 2u,\ \text{for } \mathrm{K}'=\tfrac{1}{2}\pi,\ \kappa=1,$$

degenerate case of the confocal Cassinians given by

$$(16)\qquad x+iy=a\mathrm{cn}(e\mathrm{K}+\tfrac{1}{2}\mathrm{K}'i),\ \text{or}\ \underset{\kappa'}{a}\ \mathrm{dn}(e\mathrm{K}+\tfrac{1}{2}\mathrm{K}'i).$$

Then

$$(17)\qquad \begin{aligned}\mathrm{ch}2u&=\sec 2\theta,\ \mathrm{sh}2u=\tan 2\theta,\\ \mathrm{th}\ u\ &=\tan\theta=\mathrm{cl}(1-e)\mathrm{L}.\end{aligned}$$

Important memoirs to consult on the Lemniscate Function are by Kiepert, *Crelle* 75, 1873; Schwering, *Crelle* 107, 110; Mathews, *Proceedings London Mathematical Society* 1896, 1915.

Other forms of the lemniscate integral may be given, such as that obtained from the Weierstrass integral with $g_2=-1$, $g_3=0$, and then with $s=\frac{1}{2}z^2$,

$$(18)\qquad \mathrm{L},e\mathrm{L}=\int_0^{\infty,z}\frac{dz}{\sqrt{(1+z^4)}},\qquad v=\tfrac{1}{2}\mathrm{cl}^{-1}\frac{1-z^2}{1+z^2}=e\mathrm{L}.$$

$$(19)\qquad z^2=\frac{1-\mathrm{cl}2v}{1+\mathrm{cl}2v},\quad z=\frac{\mathrm{sl}v}{\mathrm{sl}(\mathrm{L}-v)},$$

$$\mathrm{dl}2v=\frac{\sqrt{(1+z^4)}}{1+z^2},\ \mathrm{sl}2v=\frac{1}{\frac{1}{2}\left(\frac{1}{z}+z\right)},\ \mathrm{tl}2v=\frac{1}{\frac{1}{2}\left(\frac{1}{z}-z\right)}.$$

And in a Quadric Transformation, with

$$(20)\qquad \frac{1-\mathrm{sl}2v}{1+\mathrm{sl}2v}=\left(\frac{1-z}{1+z}\right)^2=x^2,\ \mathrm{cl}2v=\frac{1}{\frac{1}{2}\left(x+\frac{1}{x}\right)},$$

$$(21)\qquad v=e\mathrm{K}=\int_{\sqrt{(\frac{1}{2}\ .\ 1+6x^2+x^4)}}\frac{dx}{},$$

$$(22)\qquad x,\frac{1}{x}=\sqrt{\kappa'}\ \mathrm{tn}\left(\tfrac{1}{2}\mp e\right)\mathrm{K},\ \kappa'=\left(\sqrt{2}-1\right)^2,\ \mathrm{K}=2\mathrm{K}',$$

as in Table II.

Lemniscate Bisection : $r=45$.

2. These are given page 72, Report 1911, for the general case,

$$\mathrm{E}(45)=\frac{1}{2}(1-\kappa')=\text{hav mod. angle}=\frac{1}{2}\left(1-\frac{1}{\sqrt{2}}\right)=0{\cdot}1464466094.$$

Introducing the angle $\alpha=\phi(45)$, $\cot\alpha=\sqrt{\kappa'}$,

$$\mathrm{A}(45)=\sin 45\ (\sin 2\alpha)^{\frac{1}{4}},\ \mathrm{D}(45)=\mathrm{A}(45)\sec\alpha,$$

$$\cos\alpha=\frac{\mathrm{A}(45)}{\mathrm{D}(45)}=\sqrt{\frac{\kappa'}{1+\kappa'}}=\mathrm{cn}\frac{1}{2}\mathrm{K}.$$

$$\sin 2\alpha=\frac{2\sqrt{\kappa'}}{1+\kappa'}=2\sqrt[4]{2}(\sqrt{2}-1)$$

$2=\text{al } 0{\cdot}30102\ 99957$

$\sqrt[4]{2}=\text{al } 0{\cdot}07525\ 74989$

$\sqrt{2}-1=\text{al } \bar{1}{\cdot}61722\ 43147$

$\sin 2\alpha=\text{al } \bar{1}{\cdot}99351\ 18093$

$\sqrt[4]{\sin 2\alpha}=\text{al } \bar{1}{\cdot}99837\ 79523$

$\sin 45=\text{al } \bar{1}{\cdot}84948\ 50022$

$\mathrm{A}(45)=\text{al } \bar{1}{\cdot}84786\ 29545$

$$\mathrm{A}(45)=0{\cdot}70447\ 07318$$

$\mathrm{A}(45)=\text{al } \bar{1}{\cdot}84786\ 29545$

$\sec\alpha=\text{al } 0{\cdot}19138\ 78426$

$\mathrm{D}(45)=\text{al } 0{\cdot}03925\ 07971$

$$\mathrm{D}(45)=1{\cdot}09458\ 82886$$

$$\mathrm{sl}\tfrac{1}{2}\mathrm{L}=\sqrt{(2-\sqrt{2})},\ \mathrm{cl}\tfrac{1}{2}\mathrm{L}=\sqrt{(\sqrt{2}-1)},\ \mathrm{dl}\tfrac{1}{2}\mathrm{L}=\frac{1}{\sqrt[4]{\kappa'}},\ \mathrm{tl}\tfrac{1}{2}\mathrm{L}=\sqrt[4]{2}.$$

Lemniscate Trisection : r=30.

3. The general formulas are given in p. 72, Report 1911, as taken from *Phil. Trans.* 1904, p. 261, 'The Ellipsotomic Problem,' and for the special case of the lemniscate, where $b=2\sqrt{3}$ $\sin 75=\frac{(\sin 60)^{\frac{1}{2}}\sin 75}{(\sin 45)^{\frac{3}{2}}}$, the trigonometrical form of the division values can be written

$$D(30)=\frac{(\sin 75)^{\frac{1}{3}}}{(\sin 45)^{\frac{1}{6}}},\quad B(30)=\frac{(\sin 45)^{\frac{1}{3}}(\sin 60)^{\frac{1}{2}}}{(\sin 75)^{\frac{1}{6}}},$$

$$C(30)+A(30)=\frac{(\sin 45)^{\frac{1}{3}}}{(\sin 75)^{\frac{2}{3}}},\ C(30)-A(30)=\frac{(\sin 60)^{\frac{1}{2}}(\sin 75)^{\frac{1}{3}}}{(\sin 45)^{\frac{5}{3}}};$$

or otherwise,

$$C(30)^3+A(30)^3=\sqrt{33}/=\frac{(\sin 60)^{\frac{3}{2}}}{(\sin 45)},\ C(30)^3-A(30)^3=\frac{\sqrt{3}+1}{2}=\frac{\sin 75}{\sin 45},$$

$$E(30)=\frac{(\sin 45)^{\frac{1}{3}}(\sin 15)^{\frac{2}{3}}}{(\sin 60)^{\frac{1}{2}}},\ F(30)=E(60)=\alpha-\beta$$

$$=(\sin 45)^{\frac{1}{3}}(\sin 60)^{\frac{1}{2}}(\sin 75)^{\frac{1}{2}}-\frac{(\sin 45)^{\frac{2}{3}}(\sin 75)^{\frac{2}{3}}}{(\sin 60)^{\frac{1}{2}}}.$$

Thus for D(30)

$\sin 75$=al $\bar{1}\cdot98494\ 37781$	$(\sin 75)^{\frac{1}{3}}$=al $\bar{1}\cdot99498\ 12594$
$\sin 45$=al $\bar{1}\cdot84948\ 50022$	$(\sin 45)^{\frac{1}{6}}$=al $\bar{1}\cdot97491\ 41670$
	D(30)=al $0\cdot02006\ 70924$
	= $1\cdot04729\ 03271$

For B(30)

$\sin 45$=al $\bar{1}\cdot84948\ 50022$	$(\sin 75)^{\frac{1}{3}}$=al $\bar{1}\cdot94982\ 83340$
$\sin 60$=al $\bar{1}\cdot93753\ 06317$	$(\sin 60)^{\frac{1}{2}}$= $\bar{1}\cdot98438\ 26579$
	$\bar{1}\cdot93421\ 09919$
$\sin 75$=al $\bar{1}\cdot98494\ 37781$	$(\sin 75)^{\frac{1}{6}}$= $\bar{1}.99749\ 06297$
	B(30)=al $\bar{1}\cdot93672\ 03622$
	= $0\cdot86441\ 11542$

$$B(30)^4D(30)^2=\sin 45^\circ \sin 60^\circ.$$

For C(30) and A(30)

$\sin 60$=al $\bar{1}\cdot93753\ 06317$	$(\sin 60)^{\frac{1}{2}}$=al $\bar{1}\cdot96876\ 53158$
$\sin 75$=al $\bar{1}\cdot98494\ 37781$	$(\sin 75)^{\frac{1}{3}}$=al $\bar{1}\cdot99498\ 12593$
	$\bar{1}\cdot96374\ 65751$
$\sin 45$=al $\bar{1}\cdot84948\ 50022$	$(\sin 45)^{\frac{5}{3}}$=al $\bar{1}\cdot74914\ 16703$
	C(30)+A(30)=al $0\cdot21460\ 49048$
	= $1\cdot63909\ 79420$
$\sin 45$=al $\bar{1}\cdot84948\ 50022$	$(\sin 45)^{\frac{1}{3}}$=al $\bar{1}\cdot79931\ 33329$
$\sin 75$=al $\bar{1}\cdot98494\ 37781$	$(\sin 75)^{\frac{2}{3}}$=al $\bar{1}\cdot98996\ 25187$
	C(30)−A(30)=al $\bar{1}\cdot80935\ 08142$
	= $0\cdot64468\ 98272$
C(30)=$1\cdot14189\ 38846$,	A(30)= $0\cdot49720\ 40572$

$$A(30)^3\,C(30)^3=\sin 45^\circ \sin 15^\circ.$$

$$
\begin{aligned}
&&(\sin 45)^{\frac{1}{2}} &= \text{al } \bar{1}\cdot 92474\ 25011\\
\sin 15 &= \text{al } \bar{1}\cdot 41299\ 62306 &(\sin 15)^{\frac{1}{2}} &= \text{al } \bar{1}\cdot 11949\ 43459\\
&&&\quad \bar{1}\cdot 04423\ 68470\\
&&(\sin 60)^{\frac{1}{2}} &= \bar{1}\cdot 98438\ 26579\\
&&\mathrm{E}(30) &= \text{al } \bar{1}\cdot 05985\ 41891\\
&&&= 0\cdot 13253\ 28561\\
&&(\sin 45)^{\frac{1}{2}} &= \text{al } \bar{1}\cdot 92474\ 25011\\
&&(\sin 60)^{\frac{1}{2}} &= \text{al } \bar{1}\cdot 98438\ 26579\\
&&(\sin 75)^{\frac{1}{2}} &= \text{al } \bar{1}\cdot 99247\ 18890\\
\alpha &= (\sin 45)^{\frac{1}{2}}\,(\sin 60)^{\frac{1}{2}} &(\sin 75)^{\frac{1}{2}} &= \text{al } 1\cdot 90159\ 70480\\
&&&= 0\cdot 79725\ 46262\\
&&(\sin 45)^{\frac{3}{2}} &= \text{al } \bar{1}\cdot 77422\ 75033\\
&&(\sin 75)^{\frac{3}{2}} &= \text{al } \bar{1}\cdot 97741\ 56671\\
&&(\sin 45)^{\frac{3}{2}}\,(\sin 75)^{\frac{3}{2}} &= \text{al } \bar{1}\cdot 75164\ 31704\\
&&(\sin 60)^{\frac{1}{2}} &= \text{al } \bar{1}\cdot 92191\ 32897\\
\beta &= (\sin 45^{\frac{3}{2}}) &(\sin 75)^{\frac{3}{2}} &= \text{al } \bar{1}\cdot 82972\ 98807\\
&&(\sin 60)^{\frac{1}{2}} &= 0\cdot 67566\ 26010\\
&&\mathrm{F}(30) &= \alpha-\beta\\
&&&= 0\cdot 79725\ 46262\\
&&&- 0\cdot 67566\ 26010\\
&&&= 0\cdot 12159\ 20252
\end{aligned}
$$

This checks all the trisection values in the lemniscate table; but some other corresponding values of the elliptic function may be cited here.

Among all the trisection values for the different modular angles, the simplest appear to arise for $\theta=75°$ and there

$$\mathrm{tn}\tfrac{1}{3}\mathrm{K}=\frac{\sqrt{2}}{\sqrt[4]{3}}=\frac{1}{\sqrt{(\sin 60°)}},\quad \mathrm{dn}\tfrac{1}{3}\mathrm{K}=\frac{1}{\sqrt{2}}=\sin 45°,$$

$$\frac{\mathrm{D}(30)}{\mathrm{D}(90)}=\frac{\Theta\frac{1}{3}\mathrm{K}}{\Theta\mathrm{K}}=\frac{1}{2}\sqrt[3]{2},\quad \mathrm{D}(90)=\frac{1}{\sqrt{\kappa'}}=\frac{1}{\sqrt{(\sin 15)}},\quad \mathrm{D}(30)=\frac{\frac{1}{2}\sqrt[3]{2}}{\sqrt{(\sin 15°)}},$$

$$\mathrm{A}(30)=\frac{\sqrt{3}-1}{\sqrt[3]{4}},\quad \mathrm{C}(30)=\frac{\sqrt{3}+1}{\sqrt[3]{4}},\quad \mathrm{B}(30)=\sqrt[3]{2}\sqrt[4]{3}\sqrt{(\sin 15)},$$

$$\mathrm{E}(30)=\frac{1}{2\sqrt[4]{3}},\quad \mathrm{F}(30)=\frac{\sqrt{3}-1}{2\sqrt[4]{3}}.$$

The Table for $\theta=75°$, $\mathrm{K}=\mathrm{K}'\sqrt{3}$ is given in Report 1912, p. 52; and it might have been derived by the cubic transformation of p. 89, Report 1913, applied to the Table for $\theta=15°$, $\mathrm{K}'=\mathrm{K}\sqrt{3}$, p. 48, Report 1912, for which a q series expansion is rapidly convergent.

These division values are useful in settling the number of terms to be employed in the series.

For trisection in general, $x=\kappa \mathrm{sn}^2\frac{2}{3}\mathrm{K}$ is a root of the Jacobian quartic

$$x^4-6x^2+4\left(\frac{1}{\kappa}+\kappa\right)x-3=0.$$

$$x=\sqrt{(1+c)}+\sqrt{(1+\omega c)}+\sqrt{(1+\omega^2 c)},\ \omega^3=1,\ c^3=\frac{1}{4}\left(\frac{1}{\kappa}-\kappa\right)^2,$$

$$\frac{1}{\kappa}+\kappa=\frac{3+6x^2-x^4}{4x},\ \left(\frac{1}{\sqrt{\kappa}}\pm\sqrt{\kappa}\right)^2=\frac{3\pm 8x+6x^2-x^4}{4x},$$

$$=\frac{(1-x)^3(3+x),\text{ or }(1+x)^3(3-x)}{4x}.$$

So also, for $\mathrm{cn}\frac{2}{3}\mathrm{K}=\frac{b-1}{b+1}$, or $\mathrm{dn}\frac{2}{3}\mathrm{K}=\frac{b-1}{2}$,

$$b^4-6b^2-8b\sqrt{(1-4\kappa^2\kappa'^2)}-3=0,\ c^3=4\kappa^2\kappa'^2.$$

Thus, for the lemniscate function, with $c=\frac{1}{2}$,

$$\kappa\mathrm{sl}^2\frac{2}{3}\mathrm{K}=-\sqrt{\frac{3}{2}}+\sqrt{\frac{3+\sqrt{3}}{2}}=-\sqrt{\frac{3}{2}}+\sqrt[4]{3}\frac{\sqrt{3}+1}{2},$$

$$b^4-6b^2-3=0,\ b=\sqrt[4]{3}\,\frac{\sqrt{3}+1}{\sqrt{2}},$$

$$\mathrm{cl}\frac{1}{3}\mathrm{L}=\sqrt[4]{\frac{\cos 30}{1+\cos 30}}=\frac{\sin 45\,(\sin 60)^{\frac{1}{4}}}{\sin 75},$$

$$\mathrm{sl}\frac{1}{3}\mathrm{L}=\frac{\sqrt{3}+1+\sqrt{2}\sqrt[4]{3}}{2},\quad \mathrm{cl}\frac{2}{3}\mathrm{L}=\frac{\sqrt{3}+1-\sqrt{2}\sqrt[4]{3}}{2}=\sqrt[4]{\left(\frac{1-\sqrt{\sin 60}}{1+\sqrt{\sin 60}}\right)}$$

$$\mathrm{dl}\frac{1}{3}\mathrm{L}=\frac{\sqrt{3}-1+\sqrt{2}\sqrt[4]{3}}{2\sqrt{2}},\quad \mathrm{dl}\frac{2}{3}\mathrm{L}=\sqrt[4]{3}\,\frac{\sqrt{3}+1}{2\sqrt{2}}-\frac{1}{2}.$$

Quarter Section: $r=22\frac{1}{2}$.

4. Taking the formulas in *Phil. Trans.* 1904, p. 278, for $\mu=8$, and changing to the angle $\alpha=\phi(45)$, $\cot\alpha=\sqrt{\kappa'}$, $\tan\frac{1}{2}\alpha=a$, the expressions may be deduced

$$\mathrm{A}(22\tfrac{1}{2})^4=\frac{\sin^2(\frac{1}{4}\pi-\frac{1}{2}\alpha)\sin^2\frac{1}{2}\alpha(\sin 2\alpha)^{\frac{1}{4}}}{\sin(\frac{1}{4}\pi+\alpha)},$$

$$\mathrm{B}(22\tfrac{1}{2})^4=\frac{\sin^2(\frac{1}{4}\pi+\frac{1}{2}\alpha)\cos^2\frac{1}{2}\alpha(\sin 2\alpha)^{\frac{1}{4}}}{\sin(\frac{1}{4}\pi+\alpha)},$$

$$\mathrm{D}(22\tfrac{1}{2})^4=\frac{\cos^2\frac{1}{2}\alpha\sin(\frac{1}{4}\pi+\alpha)(\sin^2\alpha)^{\frac{1}{4}}}{2\sin^2(\frac{1}{4}\pi+\frac{1}{2}\alpha)\cos^2\alpha},$$

$$\mathrm{C}(22\tfrac{1}{2})^4=\frac{\sin^2\frac{1}{2}\alpha\sin(\frac{1}{4}\pi+\alpha)(\sin^2\alpha)^{\frac{1}{4}}}{2\sin^2(\frac{1}{4}\pi-\frac{1}{2}\alpha)\cos^2\alpha},$$

and then

$$\kappa'\,\mathrm{tn}^2\tfrac{1}{4}\mathrm{K}=\frac{\mathrm{A}(22\frac{1}{2})^2}{\mathrm{B}(22\frac{1}{2})^2}=\tan(\tfrac{1}{4}\pi-\tfrac{1}{2}\alpha)\tan\tfrac{1}{2}\alpha,$$

$$\frac{\mathrm{dn}^2\frac{1}{4}\mathrm{K}}{\kappa'}=\frac{\mathrm{C}(22\frac{1}{2})^2}{\mathrm{D}(22\frac{1}{2})^2}=\frac{\tan(\frac{1}{4}\pi-\frac{1}{2}\alpha)}{\tan\frac{1}{2}\alpha}.$$

Also

$$E(22\tfrac{1}{2})+F(22\tfrac{1}{2})=\frac{\sin(\alpha-\frac{1}{4}\pi)}{\sin\frac{1}{4}\pi\sin^2\alpha},\quad E(22\tfrac{1}{2})-F(22\tfrac{1}{2})=\frac{\sin^2(\alpha-\frac{1}{4}\pi)}{\sin^2\alpha}.$$

Thus, for example, we find for

$$K=2K',\ \kappa'=(\sqrt{2}-1)^2,\ \alpha=\frac{3}{8}\pi.$$

For the lemniscate function

$$\tan\alpha=\sqrt[4]{2},\ =\text{al } 0{\cdot}07525750=\tan 49^\circ\ 56'.$$

But taking $\alpha=50^\circ$ in a first approximation, with four-figure logarithms, as a test of the formulas,

$$\begin{aligned}
\sin(\tfrac{1}{4}\pi-\tfrac{1}{2}\alpha)&=\sin 20 &&=\text{al } \bar{1}{\cdot}5341\\
\sin\tfrac{1}{2}\alpha&=\sin 25 &&=\text{al } \bar{1}{\cdot}6259\\
\sin(\tfrac{1}{4}\pi+\alpha)&=\sin 95^\circ &&=\text{al } \bar{1}{\cdot}9983\\
\sin^2\alpha&=\sin 100 &&=\text{al } \bar{1}{\cdot}9934\\
\sin(\tfrac{1}{4}\pi+\tfrac{1}{2}\alpha)&=\sin 70^\circ &&=\text{al } \bar{1}{\cdot}9730\\
\cos\alpha&=\sin 40^\circ &&=\text{al } \bar{1}{\cdot}8081
\end{aligned}$$

Thus

$$A(22\tfrac{1}{2})^4=\frac{\sin^2 20\sin 25(\sin 80)^{\frac{1}{2}}}{\sin 85}$$
$$=\text{al } \bar{2}{\cdot}3200$$
$$A(22\tfrac{1}{2})=\text{al } \bar{1}{\cdot}5800=0{\cdot}3802$$
$$B(22\tfrac{1}{2})^4=\frac{\sin^2 70\sin^2 65(\sin 80)^{\frac{1}{2}}}{\sin 85}$$
$$=\text{al } \bar{1}{\cdot}8601$$
$$B(22\tfrac{1}{2})=\text{al } \bar{1}{\cdot}9650=0{\cdot}9226$$
$$D(22\tfrac{1}{2})^4=\frac{\sin^2 65\sin 85(\sin 80)^{\frac{1}{2}}}{2\sin^2 70\sin^2 40}$$
$$=\text{al } 0{\cdot}0481$$
$$D(22\tfrac{1}{2})=\text{al } 0{\cdot}0120=1{\cdot}026$$
$$C(22\tfrac{1}{2})^4=\frac{\sin^2 25\sin 85(\sin 80)^{\frac{1}{2}}}{2\sin^2 20\sin^2 40}$$
$$=\text{al } 0{\cdot}2630$$
$$C(22\tfrac{1}{2})=\text{al } 0{\cdot}06575=1{\cdot}163.$$

Testing $r=22\frac{1}{2}$ in Table II, where the angle α is exactly three quarters of a right angle,

$$\alpha=\frac{3}{8}\pi,\ \frac{1}{4}\pi-\frac{1}{2}\alpha=\frac{\pi}{16},\ \frac{1}{4}\pi+\frac{1}{2}\alpha=\frac{7\pi}{16},\ \frac{1}{4}\pi+\alpha=\frac{5}{8}\pi,$$

$$A(22\tfrac{1}{2})^4=\frac{\sin^2 11^\circ\tfrac{1}{4}\ \sin^2 33\tfrac{3}{4}\ (\sin 45)}{\sin 67^\circ\tfrac{1}{2}}$$

$$B(22\tfrac{1}{2})^4=\frac{\sin^2 78^\circ\tfrac{3}{4}\sin^2 56^\circ\tfrac{1}{4}\ (\sin 45)^{\frac{1}{2}}}{\sin 67^\circ\tfrac{1}{2}}$$

$$D(22\tfrac{1}{2})^4=\frac{\sin^2 56^\circ\tfrac{1}{4}\sin 67^\circ\tfrac{1}{2}\ (\sin 45)}{2\sin^2 78^\circ\tfrac{3}{4}\sin^2 22^\circ\tfrac{1}{2}}$$

$$C(22\tfrac{1}{2})^4=\frac{\sin^2 33^\circ\tfrac{3}{4}\sin 67^\circ\tfrac{1}{2}\ (\sin 45)}{2\sin^2 11^\circ\tfrac{1}{4}\sin^2 22^\circ\tfrac{1}{2}}$$

$$E(22\tfrac{1}{2})+F(22\tfrac{1}{2})=\frac{\sin 22\tfrac{1}{2}}{\sin 75 \sin^2 67°\tfrac{1}{2}},\ E(22\tfrac{1}{2})-F(22\tfrac{1}{2})=\frac{\sin^2 22°\tfrac{1}{2}}{\sin^2 67°\tfrac{1}{2}}.$$

Here the seven or ten figure logarithms may be used in the test calculation.

But tested with ordinary seven figure logarithms

$$A(22\tfrac{1}{2})^4=\frac{\sin^2 11°15'\sin^2 33°45'(\sin 45)^{\frac{1}{2}}}{\sin 67°30'}$$

$$B(22\tfrac{1}{2})^4=\frac{\sin^2 78°45'\sin^2 56°15'(\sin 45)^{\frac{1}{2}}}{\sin 67°30'}$$

$A(22\tfrac{1}{2})^4$ = al $\bar{2}\cdot0667053$

$A(22\tfrac{1}{2})$ = al $\bar{1}\cdot5166763 = 0\cdot32860$

$$\frac{B(22\tfrac{1}{2})^4}{A(22\tfrac{1}{2})^4}=\tan^2 78°45'\tan^2 56°15'$$

$$\frac{B(22\tfrac{1}{2})}{A(22\tfrac{1}{2})}=\text{al } 0\cdot4382228$$

$A(22\tfrac{1}{2})$ = al $1\cdot5166763$

$B(22\tfrac{1}{2})$ = al $\bar{1}\cdot9548991 = 0\cdot90136$

$$D(22\tfrac{1}{2})^4=\frac{\sin^2 56°15'\sin 67°30'(\sin 45)^{\frac{1}{2}}}{2\sin^2 78°45'\sin^2 22°30'}$$

$D(22\tfrac{1}{2})^4$ = al $0\cdot3178220$

$D(22\tfrac{1}{2})$ = al $0\cdot0794555 = 1\cdot2008\ldots$

$$C(22\tfrac{1}{2})^4=\frac{\sin^2 33°45'\sin 67°30'(\sin 45)^{\frac{1}{2}}}{2\sin^2 11°15'\sin^2 2°30'}$$

$$\frac{C(22\tfrac{1}{2})^4}{D(22\tfrac{1}{2})^4}=\tan^2 33°45'\tan^2 78°45'$$

$$\frac{C(22\tfrac{1}{2})}{D(22\tfrac{1}{2})}=\text{al } 0\cdot2630154$$

$D(22\tfrac{1}{2})$ = al $0\cdot0794555$

$C(22\tfrac{1}{2})$ = al $0\cdot3424709 = 2\cdot2003$

$E-F=\tan^2 22°30'$

$= \text{al } \bar{1}\cdot2344486 = 0\cdot171573$

$$E+F=\frac{\tan 22°30'}{\sin 45°\sin 67°30'}$$

$= \text{al } \bar{1}\cdot8021240 = 0\cdot634051$

$E(22\tfrac{1}{2}) = 0\cdot402812$

$F(22\tfrac{1}{2}) = 0\cdot231239$

Lemniscate 5 section: $r=18, 36$.

5. The formulas to be employed are given on p. 7, Report 1911, where we put

$$a_1=\frac{(c-1)\,(c^2-4c-1)}{(c+1)^3},\quad a_2=\frac{(c+1)\,(c^2-4c-1)}{(c-1)^3}$$

$$c_1=\frac{(c+1)^{\frac{2}{5}}\,(c-1)^{\frac{2}{5}}}{2c^{\frac{1}{5}}},\quad c_2=\frac{(c+1)^{\frac{1}{5}}\,(c-1)^{\frac{4}{5}}}{2c^{\frac{2}{5}}}$$

$$e_1=c_1\sqrt[4]{a_1}=\frac{(c+1)^{\frac{1}{10}}\,(c-1)^{\frac{9}{20}}\,(c^2-4c-1)^{\frac{1}{4}}}{2c^{\frac{3}{5}}},$$

$$e_2=c_2\sqrt[4]{a_2}=\frac{(c+1)^{\frac{9}{10}}\,(c-1)^{\frac{1}{20}}\,(c^2-4c-1)^{\frac{1}{4}}}{2c^{\frac{2}{5}}}$$

$$c_1c_2=\tfrac{1}{4}(c-\tfrac{1}{c}),\quad e_1e_2=\tfrac{1}{4}(c-\tfrac{1}{2})^{\frac{1}{2}}\,(c-\tfrac{1}{c}-4)^{\frac{1}{2}}$$

taken from Phil. Trans. 1904, p. 264; and apply the numerical values of c in the three regions, I, II, III. And with

$$b_1=\frac{(c+3)\,(c^2-4c-1)}{20c^{\frac{3}{5}}(c-\frac{1}{c}+1)^{\frac{1}{4}}},\quad b_2=\frac{(3c-1)\,(c^2-4c-1)}{20c^{\frac{3}{5}}(c-\frac{1}{c}+1)^4}$$

$$2b_2-b_1=\frac{(c-1)\,(c^2-4c-1)}{4c^{\frac{3}{5}}(c-\frac{1}{c}+1)^{\frac{1}{4}}}=\frac{(c-\frac{1}{c}-2)\,(c-\frac{1}{c}-4)}{4(-\frac{1}{c}+1)^{\frac{1}{4}}}$$

$$b_2+2b_1=\frac{(c+1)\,(c^2-4c-1)}{4c^{\frac{3}{5}}(c-\frac{1}{c}+1)^{\frac{1}{4}}}=\frac{(c+\frac{1}{c}+2)^{\frac{1}{2}}\,(c-\frac{1}{c}-4}{4(c-\frac{1}{c}+1)^{\frac{1}{4}}}$$

Region II.

$$\mathrm{C}(36)=\frac{c_1}{\sqrt{\kappa}},\ \mathrm{D}(18)=\frac{c_2}{\sqrt{\kappa}},\ \mathrm{A}(36)=\frac{e_1}{\sqrt{\kappa}},\ \mathrm{B}(18)=\frac{e_1}{\sqrt{\kappa}}$$

$$c-\frac{1}{c}=4\sin 54,\ c+\frac{1}{c}=4\sin 72$$

$$c=2\sin 72+2\sin 54=4\sin 63\sin 81$$

$$c-\frac{1}{c}-4=-8\sin^2 18,\ c-\tfrac{1}{2}+1=8\sin^3 54=(2\sin 54)^3$$

$$c+\frac{1}{c}-2=4\sin 72+4\sin 30=8\sin 51\sin 69$$

$$c+\frac{1}{c}-2=4\sin 72-4\sin 30=8\sin 39\sin 21$$

$$c_1{}^{10}=\frac{2\sin^3 51\sin^3 69\sin^2 54}{\sin 63\sin 81},\quad c_2{}^{10}=32\sin 63\sin 81\sin^3 39\sin^3 21\sin^2 54$$

$$e_1{}^{10}=\frac{2\sin^4 54\sin^5 18\sin^2 39\sin^2 21}{\sin 45\sin 63\sin 81}$$

$$e_2{}^{10}=\frac{32\sin^4 54\sin^5 18\sin^2 51\sin^2 69\sin 63\sin 81}{\sin^3 45}$$

$$\mathrm{cl}\tfrac{4}{5}\mathrm{L}=\frac{\sqrt{\frac{\sqrt{5}+1}{2}+\sqrt[4]{5}-\frac{\sqrt{5}+1}{2}}}{\sqrt{\frac{\sqrt{5}+1}{2}+\sqrt[4]{5}+\frac{\sqrt{5}+1}{2}}}=\cos 74°8,$$

$$\mathrm{cl\ L}=\frac{\frac{\sqrt{5}+1}{2}+\sqrt{\frac{\sqrt{5}+1}{2}-\sqrt[4]{5}}}{\frac{\sqrt{5}+1}{2}+\sqrt{\frac{\sqrt{5}+1}{2}+\sqrt[4]{5}}}=\cos 40°\ 75.$$

Legendre, F. E. II. p. 283, has calculated

$$\phi(9)=10°\,.\,59286766=10°\ 35'\ 34''\,.\,3235850$$

which can be used in a numerical test.

Numerical Calculation: for c_1

sin 51	al $\bar{1}$·89050 25944	$\sin^3 51$	al 1·67150 77832
sin 69	$\bar{1}$·97015 17377	$\sin^3 69$	$\bar{1}$·91045 52131
sin 54	$\bar{1}$·90795 76446	$\sin^2 54$	$\bar{1}$·81591 52892
		2	0·30102 99957
sin 63	$\bar{1}$·94988 08840	N	al $\bar{1}$·69890 82812
sin 81	$\bar{1}$·99461 99270	D	al $\bar{1}$·94450 08110
D	al $\bar{1}$·94450 08110		

$$c_1^{10}=\frac{\mathrm{N}}{\mathrm{D}}=\text{al } \bar{1}\cdot75440\ 74702$$

$$c_1=\text{al } \bar{1}\cdot97544\ 07470$$

$$\frac{1}{\sqrt{\kappa}}=\sqrt[4]{2}=\text{al } 0\cdot07525\ 74990$$

$$\mathrm{C}(36)=\frac{c_1}{\sqrt{\kappa}}=\text{al } 0\cdot05069\ 82460$$

$$=\ 1\cdot12382\ 38537$$

For c_2

sin 39	al $\bar{1}$·79887 18039	$\sin^3 39$	al 1·39661 54117
sin 21	$\bar{1}$·55432 91617	$\sin^3 21$	$\bar{2}$·66298 74851
sin 54	$\bar{1}$·90795 76446	$\sin^2 54$	$\bar{1}$·81591 52892
sin 63	$\bar{1}$·94988 08840	sin 63	$\bar{1}$·94988 08840
sin 81	$\bar{1}$·99461 99270	sin 81	$\bar{1}$·99461 99270
2	0·30102 99957	2^5	1·50514 99785
		c_2^{10}	al $\bar{1}$·32516 89755
		c_2	al $\bar{1}$·93251 68975
		$\frac{1}{\sqrt{\kappa}}$	al 0·07525 74990

$$\mathrm{D}(18)=\frac{c_2}{\sqrt{\kappa}}=\text{al } 0\cdot00777\ 43965$$

$$=\ 1.01806\ 23965$$

$$c(36)\mathrm{D}(18)=\frac{c_1 c_2}{\kappa}=\frac{\sin 54}{\sin 45}$$

Numerical Calculation: for e_1.

$\sin 54 = \text{al } 1\cdot90795\ 76446$ $\quad (\sin 54)^{\frac{1}{3}} = \text{al } \bar{1}\cdot95397\ 88223$

$\sin 39 = \text{al } \bar{1}\cdot79887\ 18039$ $\quad (\sin 39)^{2} = \text{al } \bar{1}\cdot59774\ 36078$

$\sin 21 = \text{al } \bar{1}\cdot55432\ 91618$ $\quad (\sin 21)^{2} = \text{al } \bar{1}\cdot10865\ 83236$

$\sin 18 = \text{al } \bar{1}\cdot48998\ 23641$ $\quad (\sin 18)^{5} = \text{al } \bar{3}\cdot44991\ 18205$

$\text{N} = \text{al } \bar{4}\cdot11029\ 25743$

$\sin 45 = \text{al } 1\cdot84948\ 50022$ $\quad (\sin 45)^{10} = \text{al } \bar{2}\cdot49485\ 00220$

$\sin 63 = \text{al } \bar{1}\cdot94988\ 08841$ $\quad \sin 63 = \text{al } \bar{1}\cdot94988\ 08841$

$\sin 81 = \text{al } 1\cdot99461\ 99271$

$\text{D} = \text{al } 2\cdot43935\ 08332$

$$\text{A}(36)^{10} = \frac{\text{N}}{\text{D}} = \text{al } \bar{3}\cdot67094\ 17411$$

$$\text{A}(36) = \frac{e_1}{\sqrt{\kappa}} = \text{al } \bar{1}\cdot76709\ 41741$$

$$= 0\cdot58491\ 69061$$

For e_2 and B(18),

$(\sin 54)^{\frac{1}{3}} = \text{al } \bar{1}\cdot95397\ 88223$

$\sin 63 = \text{al } \bar{1}\cdot94988\ 08841$

$\sin 81 = \text{al } \bar{1}\cdot99461\ 99271$

$\sin 51 = \text{al } \bar{1}\cdot89050\ 25945$ $\quad (\sin 51)^{2} = \text{al } \bar{1}\cdot78100\ 51890$

$\sin 69 = \text{al } \bar{1}\cdot97015\ 17377$ $\quad (\sin 69)^{2} = \text{al } \bar{1}\cdot94030\ 34754$

$\sin 18 = \text{al } \bar{1}\cdot48998\ 23641$ $\quad (\sin 18)^{5} = \text{al } \bar{3}\cdot44991\ 18205$

$\text{N} = \text{al } \bar{3}\cdot06970\ 01184$

$\sin 45 = \text{al } 1\cdot84948\ 50022$; $\quad \text{D} = (\sin 45)^{18} = \text{al } 3\cdot29073\ 00396$

$$\text{B}(18)^{10} = \frac{\text{N}}{\text{D}} = \text{al } \bar{1}\cdot77897\ 00788$$

$$\text{B}(18) = \frac{e_2}{\sqrt{\kappa}} = \text{al } \bar{1}\cdot97789\ 70079$$

$$= 0\cdot95037\ 93863$$

$$\text{A}(36)\text{B}(18) = \frac{e_1 e_2}{\kappa} = 2(\sin 54^\circ)^{\frac{1}{3}} \sin 18^\circ.$$

In Region I, $c = \text{D}(36)$, $c_2 = \text{C}(18)$

with $\frac{1}{2}\left(c - \frac{1}{c}\right) = \sqrt[4]{5} + 1 = 2 \sin 72 \sqrt{(2 \sin 18)} + 1$

$\frac{1}{2}\left(c + \frac{1}{c}\right) = 2 \sin 72 + \sqrt{(2 \sin 18)}$

$$c_1^5 + c_2^5 = \frac{(c+1)^4(c-1)}{32c^3} + \frac{(c+1)(c-1)^4}{32c^2}$$

$$= \frac{1}{32}\left(c - \frac{1}{c}\right)\left[\left(c - \frac{1}{c}\right)^2 - 2\left(c - \frac{1}{c}\right) + 8\right]$$

$$=\frac{1}{4}(\sqrt[4]{5}+1)(\sqrt{5}+\sqrt[4]{5}+2)=\frac{1}{4}\sqrt[4]{5}(\sqrt{}+3)+\frac{1}{2}(\sqrt{5}+1)$$

$$=(2\sin 54)^{\frac{3}{2}}\sin 72+2\sin 54$$

$$2\sin 54=\frac{1}{2}(\sqrt{5}+1)= \quad 1{\cdot}61803\ 39888$$

$$=\text{al}\ 0{\cdot}20898\ 76403$$

$$(2\sin 54)^{\frac{3}{2}}=\text{al}\ 0{\cdot}31348\ 14604$$

$$\sin 72\ =\text{al}\ \bar{1}{\cdot}97820\ 63255$$

$$(2\sin 54)^{\frac{3}{2}}\sin 72\ =\text{al}\ 0{\cdot}29168\ 77859$$

$$=\quad 1{\cdot}95713\ 69676$$

$$c_1^5+c_2^5= \quad 3{\cdot}57547\ 09563$$

$$c_2^5-c_1^5=\frac{1}{32}\left(c-\frac{1}{c}\right)\left(c-\frac{1}{c}-4\right)\left(c+\frac{1}{c}\right)$$

$$=\frac{1}{4}\left(\sqrt{5}-1\right)\frac{1}{2}\left(c+\frac{1}{c}\right)$$

$$=\sin 18[2\sin 72+\sqrt{(2\sin 18)}]$$

$$=\sin 36+\frac{(\sin 18)^{\frac{3}{2}}}{\sin 45}$$

$$\frac{(\sin 18)^{\frac{3}{2}}}{\sin 45}=0{\cdot}24293\ 41359$$

$$\sin 36\ =0{\cdot}58778\ 52523$$

$$c_2^5-c_1^5\ =0{\cdot}83071\ 93882$$

$$c_1^5\ =1{\cdot}37237\ 57840=\text{al}\ 0{\cdot}13747\ 30637$$

$$c_1\ =1{\cdot}06535\ 56397=\text{al}\ 0{\cdot}02749\ 46127=\text{D}(36)$$

$$c_2^5\ =2{\cdot}20309\ 51722=\text{al}\ 0{\cdot}34303\ 32570$$

$$c_2\ =1{\cdot}17113\ 41680=\text{al}\ 0{\cdot}06860\ 66514=\text{C}(18)$$

$$\text{C}(18)\text{D}(36)=c_1c_2=\frac{1}{2}(\sqrt[4]{5}+1)$$

In Region III, $c_1=\text{B}(36)$, $c_2=-\text{A}(18)$,

$$\tfrac{1}{2}\left(c-\frac{1}{c}\right)=-\sqrt[4]{5}+1=-2\sin 72\,(\sin 18)+1$$

$$\tfrac{1}{2}\left(c+\frac{1}{c}\right)=\quad 2\sin 72-\sqrt{(2\sin 18)}$$

$$c_1^5+c_2^5=-(2\sin 54)^{\frac{3}{2}}\sin 72+2\sin 54= \quad 0{\cdot}33940\ 29785$$

$$c_1^5-c_2^5=-\sin 36-\frac{(\sin 18)^{\frac{3}{2}}}{\sin 45} \quad = \quad 0{\cdot}34485\ 11165$$

$$c_1^5= \quad 0{\cdot}34212\ 70475 \quad =\text{al}\ \bar{1}{\cdot}53418\ 74095$$

$$c_1=\text{al}\ \bar{1}{\cdot}90683\ 74819 \quad = \quad 0{\cdot}80693\ 30099=\text{B}(36)$$

$$-c_2^5= \quad 0{\cdot}00272\ 40690 \quad =\text{al}\ \bar{3}{\cdot}43521\ 81065$$

$$-c_2=\text{al}\ \bar{1}{\cdot}48704\ 36213 \quad = \quad 0{\cdot}30673\ 30262=\text{A}(18)$$

$$\text{A}(18)\text{B}(36)=-c_1c_2=\tfrac{1}{2}(\sqrt[4]{5}-1).$$

In Region II, $b_1=\frac{E(18)}{\sqrt{\kappa}}$, $b_2=\frac{F(36)}{\sqrt{\kappa}}$,

$$2b_2-b_1=\frac{4\sin^{\frac{1}{2}}39\sin^{\frac{1}{2}}21\sin^2 18}{\sin^{\frac{3}{2}}54},\quad b_2+2b_1=\frac{4\sin^{\frac{1}{2}}51\sin^{\frac{1}{2}}69\sin^2 18}{\sin^{\frac{3}{2}}54}$$

$$\frac{2b_2-b_1}{b_2+2b_1}=\tan^{\frac{1}{2}}39\tan^{\frac{1}{2}}21.$$

$\tan 39=\text{al }\bar{1}\cdot90836\ 92094$ $\qquad$ $\tan^{\frac{1}{2}}39=\text{al }\bar{1}\cdot95418\ 46047$

$\tan 21=\text{al }\bar{1}\cdot58417\ 74241$ $\qquad$ $\tan^{\frac{1}{2}}21=\text{al }1\cdot79208\ 87121$

$\qquad\qquad\qquad

and the verification can be carried out with the formulas given above for b_1 and b_2, $2b_2-b_1$ and b_2+2b_1, taking $(c-\frac{1}{c})=\sqrt[4]{5}+1$ in Region I as before, and working with

$$(2b_2-b_1)(b_2+2b_1)=\tfrac{1}{16}\frac{(c-\frac{1}{2})(c-\frac{1}{c}-4)^2}{(c-\frac{1}{c}+1)^{\frac{1}{2}}}, \quad \frac{2b_2-b_1}{b_2+2b_1}=\frac{c-1}{c+1}.$$

It is not difficult to determine the value of c in a quinquisection for $K=2K'$, and to make the algebraical numerical verifications in Table II.

Lemniscate Seven Section.

6. With the Weierstrass functions of the First Stage, as defined in *Phil. Trans.* 1904, p. 250, and in the $2n+1$ section of a period,

$$(1)\quad \gamma_{2n+1}=0,\ \lambda=\frac{\gamma_{n+1}}{\gamma_n},\ \lambda^3=\frac{\gamma_{n+2}}{\gamma_{n-1}},\ \ldots\ldots,\ f=\frac{1}{2n+1},\ r=90f.$$

$$(2)\quad \mathrm{A}(2r)\ =\sqrt[4]{(e_1-e_2\,.\,e_1-e_3)}\,x^{-\frac{1}{3}}\lambda^{-\frac{1}{2n\times 1}},$$

$$(3)\quad \mathrm{A}(2pr)=\sqrt[4]{(e_1-e_2\,.\,e_1-e_3)}\,x^{-\frac{1}{3}}\lambda^{-\frac{p^2}{2n+1}}\gamma_p,$$

but still requiring the condition of the Second Stage, that the factors of S should be known.

But with the Lemniscate Function, where

$$(4)\quad g_3=0,\ \Delta={g_2}^3=(e_1-e_3)^6=64(e_1-e_2)^6=64(e_2-e_3)^6$$

$$(5)\quad \mathrm{A}(2r)=\left(\frac{1}{8}\Delta\right)^{\frac{1}{12}}x^{-\frac{1}{3}}\lambda^{-\frac{1}{2n+1}},$$

$$\mathrm{A}(2pr)=\left(\frac{1}{8}\Delta\right)^{\frac{1}{12}}x^{-\frac{1}{3}}\lambda^{-\frac{p^2}{2n+1}}\gamma_p.$$

Turning to the case of $2n+1=7$, *Phil. Trans.*, §9, p. 230, and *Proc. L.M.S.*, 1893–4, p. 223, where Klein's modular equation is

$$\mathrm{J}:\mathrm{J}-1:1=(\tau^2+13\tau+49)(\tau^2+5\tau+1)^3:(\tau^4+14\tau^3+63\tau^2+70\tau-7)^2:1728\tau,$$

$$\tau=\frac{1-8z+5z^2+z^3}{z(1-z)},\quad \tau+\frac{13}{2}=\frac{(1+z)\,.\,(2-z)\,.\,(1-2z)}{2z\,.\,1-z},$$

$$\tau^2+13\tau+49=\left(\tau+\frac{13}{2}\right)^2+\frac{27}{4}=\frac{(1-z+z^2)^3}{z^2(1-z)^2}=\frac{27}{4}\operatorname{cosec}^2 3\theta,\ \text{if}$$

$$\tau+\frac{13}{2}=\frac{3}{2}-z-\frac{1}{1-z}-\frac{z-1}{z}=\frac{3}{2}\sqrt{3}\cot 3\theta;$$

and then, according to Mr. Alfred Lodge, the three roots of this cubic equation for z, when τ is given and the auxiliary angle θ, are given by

$$z=\frac{\sin\theta}{\sin(60+\theta)},\ \frac{1}{1-z}=\frac{\sin(60+\theta)}{\sin(120+\theta)},\ \frac{z-1}{z}=\frac{\sin(120+\theta)}{\sin(180+\theta)}.$$

The lemniscate condition, J=1, requires

$$\tau^4+14\tau^3+63\tau^2+70\tau-7=(\tau^2+7\tau+21)^2-7(2\tau+8)^2=0,$$

$$\tau=\frac{-7+2\sqrt{7}}{2}+\frac{\sqrt{7}-1}{2\sqrt{2}}\sqrt[4]{7}=0{\cdot}09219\ 27\ \ldots\ldots$$

$$2\tau+13=13{\cdot}1843854,\ \cot 3\theta=\mathrm{al}\ 0{\cdot}4043780=\cot 21^\circ\ 30'.606$$

$$z=\frac{\sin 7^\circ\ 10'.202}{\sin 67^\circ\ 10'.202}=\mathrm{al}\ \frac{\bar{1}{\cdot}0960644}{\bar{1}{\cdot}9645709}=\mathrm{al}\ \bar{1}{\cdot}1316935=0{\cdot}1354233$$

$$\frac{1}{1-z}=\frac{\sin 67^\circ\ 10'\,.\,202}{\sin 127^\circ\ 10'.\,202}=\mathrm{al}\ \frac{\bar{1}{\cdot}9645709}{\bar{1}{\cdot}9013744}=\mathrm{al}\ 0{\cdot}0631965=1{\cdot}1566355$$

$$-\frac{z-1}{z}=\frac{\sin 127^\circ\ 10'.202}{-\sin 187^\circ\ 10'.202}=\mathrm{al}\ \frac{\bar{1}{\cdot}9013744}{\bar{1}{\cdot}0960644}=\mathrm{al}\ 0{\cdot}8051100=6{\cdot}384251$$

Here, in *Proc. L.M.S.* 1898–4, p. 223,

$$\Delta = z^7(1-z)^7(1-8z+5z^2+z^3) = z^8(1-z)^8\tau,$$

with $\gamma_7=0$, $x=z(1-z)^2$, $y=z(1-z)$, $\lambda=\dfrac{\gamma_4}{\gamma_3}=\dfrac{y}{x^{\frac{1}{3}}}=z^{\frac{2}{3}}(1-z)^{\frac{1}{3}}$

$$A(2r)=\left(\frac{1}{8}\tau\right)^{\frac{1}{12}} z^{\frac{5}{21}}\ (1-z)^{-\frac{1}{21}}$$

$$A(4r)=\left(\frac{1}{8}\tau\right)^{\frac{1}{12}} z^{-\frac{1}{21}} (1-z)^{-\frac{4}{21}}$$

$$A(6r)=\left(\frac{1}{8}\tau\right)^{\frac{1}{12}} z^{-\frac{4}{21}} (1-z)^{\frac{5}{21}}$$

$$\frac{1}{8}\tau = 0{\cdot}011524088$$

$$= \text{al } 2{\cdot}0616065$$

$$\left(\frac{1}{8}\tau\right)^{\frac{1}{12}} = \text{al } \bar{1}{\cdot}8384672$$

$$z^{\frac{5}{21}} = \text{al } \bar{1}{\cdot}7932604$$

$$\left(\frac{1}{1-z}\right)^{\frac{1}{21}} = \text{al } 0{\cdot}0030094$$

$$A(2r) = \text{al } \bar{1}{\cdot}6347369 = 0{\cdot}4312577 = A\left(\frac{180}{7}\right)$$

$$\frac{A(4r)}{A(2r)} = z^{-\frac{2}{7}}(1-z)^{-\frac{1}{7}}$$

$$z^{\frac{2}{7}} = \text{al } \bar{1}{\cdot}7519124$$

$$\left(\frac{1}{1-z}\right)^{\frac{1}{7}} = \text{al } 0{\cdot}0090281$$

$$\frac{A(4r)}{A(2r)} = \text{al } 0{\cdot}2571157$$

$$A(2r) = \text{al } \bar{1}{\cdot}6347369$$

$$A(4r) = \text{al } \bar{1}{\cdot}8918526 = 0{\cdot}7795654 = A\left(\frac{360}{7}\right)$$

$$\frac{A(6r)}{A(2r)} = z^{-\frac{3}{7}}(1-z)^{\frac{2}{7}}$$

$$A(6r) = \text{al } \bar{1}{\cdot}9888121 = 0{\cdot}9745680 = A\left(\frac{540}{7}\right)$$

$$A(2r)A(4r)A(6r) = \left(\frac{1}{8}\tau\right)^{\frac{1}{4}}.$$

$$\frac{A(2r)^2}{C(2r)^2}=\mathrm{cl}^2(1-2f)L=\frac{s_1-s_2}{s-s_2}=\frac{\frac{1}{2}\Delta^{\frac{1}{6}}}{P_1},\ P_1=\frac{(1+y)^2+4x}{12},$$

$$C(2r)^2=x^{-\frac{2}{3}}\lambda^{-\frac{2}{2n+1}}P_1\sqrt{2}$$

$$C(4r)^2=x^{-\frac{2}{3}}\lambda^{-\frac{8}{2n+1}}P_2\sqrt{2}$$

. . . . . .

$$C(2pr)^2=x^{-\frac{2}{3}}\lambda^{-\frac{2p^2}{2n+1}}\gamma_p{}^2P_p\sqrt{2},$$

$$12P_1=(1+y)^2+4x,\ 12P_2=(1+y)^2-8x,$$

$$2P_1+P_2=\frac{1}{4}\left(1+y\right)^2$$

$$P_1-P_2=x,\ P_1-P_3=y,\ P_1-P_4=z(1-z),\quad . . . . . .$$

$$\frac{C(2pr)^2}{C(2r)^2}=\lambda^{-2\frac{p^2-1}{2n+1}}\gamma_p{}^2\frac{P_p}{P_1}.$$

Then

$$x=p\frac{2\mu\omega}{7}=\frac{2}{\mathrm{cl}^2\left(1-\frac{2\mu}{7}\right)L}=\frac{P\mu}{6z^{\frac{1}{3}}(1-z)^{\frac{1}{3}}\left(\frac{1}{8}\tau\right)^{\frac{1}{6}}}$$

is a root of the equation $\Psi_7=0$, given by Mathews, *Proc. L.M.S.*, 1915, p. 464; and

$$p\frac{2\omega}{7}+p\frac{4\omega}{7}+p\frac{6\omega}{7}=\frac{\frac{1}{4}(1-z+z^2)^2}{6z^{\frac{1}{3}}(1-z)^{\frac{1}{3}}\left(\frac{1}{8}\tau\right)^{\frac{1}{6}}},$$

$$\begin{aligned}
z&=\mathrm{al}\ \bar{1}\cdot1316935\\
1-z&=\mathrm{al}\ \bar{1}\cdot9368085\\
y&=\mathrm{al}\ \bar{1}\cdot0684970=0\cdot1170839\\
x=z(1-z)^2&=\mathrm{al}\ \bar{1}\cdot0053005=0\cdot1012280\\
\lambda^3=z^2(1-z)&=\mathrm{al}\ \bar{2}\cdot2001905=0\cdot0158559\\
\lambda&=\mathrm{al}\ \bar{1}\cdot4000635\\
\lambda^{-1}&=\mathrm{al}\ 0\cdot5999365\\
\lambda^{-\frac{1}{7}}&=\mathrm{al}\ 0\cdot0857052\\
x^{-1}&=\mathrm{al}\ 0\cdot9946995\\
x^{-\frac{1}{3}}&=\mathrm{al}\ 0\cdot3315665\\
x^{-\frac{2}{3}}&=\mathrm{al}\ 0\cdot6631330\\
\lambda^{-\frac{2}{7}}&=\mathrm{al}\ 0\cdot1714104\\
1+y&=\mathrm{al}\ 0\cdot0480858=1\cdot1170839\\
(1+y)^2&=\mathrm{al}\ 0\cdot0961716\\
4&=\mathrm{al}\ 0\cdot6020600\\
2P_1+P_2&=\mathrm{al}\ \bar{1}\cdot4941116=0\cdot3119691\\
P_1-P_2&=x\qquad\qquad=0\cdot1012280
\end{aligned}$$

$$3P_1 = 0{\cdot}4131971, \quad P_1 = 0{\cdot}1377324$$
$$y = 0{\cdot}1170839$$
$$P_2 = P_1 - x = 0{\cdot}0365044$$
$$P_3 = P_1 - y = 0{\cdot}0206485$$
$$\text{(check) } P_2 - P_3 = \lambda^3 = 0{\cdot}0158559$$

$$C(2r)^2 = x^{-\frac{2}{3}} \lambda^{-\frac{2}{7}} P_1 \sqrt{2}$$
$$= \text{al } 0{\cdot}1240945$$
$$C(2r) = \text{al } 0{\cdot}0620472 = 1{\cdot}153579$$
$$\frac{C(4r)^2}{C(2r)^2} = \lambda^{-\frac{6}{7}} \frac{P_2}{P_1}$$
$$= \text{al } \bar{1}{\cdot}9375405$$
$$C(2r)^2 = \text{al } 0{\cdot}1240945$$
$$C(4r)^2 = \text{al } 0{\cdot}0616350$$
$$C(4r) = \text{al } 0{\cdot}0308175 = 1{\cdot}073538$$
$$C(6r)^2 = \lambda^{-\frac{18}{7}} P_3 \sqrt{2}$$
$$= \text{al } 0{\cdot}0080973$$
$$C(6r) = \text{al } 0{\cdot}0040486 = 1{\cdot}0093660$$

Considering the uncertainty involved in working with only 7 figure logarithms. the agreement is quite close with the numbers calculated by Colonel Hippisley from the series given in Table V.

Seventeen Section values are given, too, in Table VI, to serve for future reference.

These numerical verifications of Seven Section, as well as of Nine Section, in § 7 were carried out by Mr. Alfred Lodge. He has shown also that, for the Seven Section,

$$C(2r)\ C(4r)\ C(6r) = (\tau^2 + 9\tau + 17) \div 12(2^{\frac{1}{4}}),$$

which serves therefore as a check on the calculations. Thus

$$\tau^2 + 9\tau + 17 = 17{\cdot}8382328 = \text{al } 1{\cdot}2513519$$
$$12(2)^{\frac{1}{4}} = \quad = \text{al } 1{\cdot}1544387$$
$$C(2r)\ C(4r)\ C(6r) \quad = \text{al } 0{\cdot}0969132.$$

And in the calculations above

$$C(2r) \quad = \text{al } 0{\cdot}0620473$$
$$C(4r) \quad = \text{al } 0{\cdot}0308075$$
$$C(6r) \quad = \text{al } 0{\cdot}0040486$$
$$C(2r)\ C(4r)\ C(6r) \quad = \text{al } 0{\cdot}0969133.$$

Lemniscate Nine Section; $r=10$.

7. Here, in *L.M.S.* 1893, p. 233, with $\xi+3=x$, the modular equation of the 9th order becomes

$$J : J-1 : 1=x^3(x^3-24)^3 : (x^6-36x^3+216)^2 : 1728(x^3-27),$$

so that the lemniscate condition, $J=1$, requires

$$x^6-36x^3+216=0,\ x^3=18+6\sqrt{3},\ x=\sqrt{3}\sqrt[3]{(2\sqrt{3}+2)}$$

$$x=\text{al } 0\cdot4844002 \qquad =3\cdot050705\ \ldots.$$

Then from *Phil. Trans.* 1904, p. 231, § 10,

$$\gamma_9=0,\ x=p^2(1-p)(1-p+p^2),\ y=p^2(1-p),\ \lambda=\frac{\gamma_5}{\gamma_4}=1-\frac{x}{y}=p(1-p),$$

$$\Delta=p^{12}(1-p)^{12}(x^3-27),\ \text{with } x^3-27=6\sqrt{3}-9=1\cdot3923048\ldots.$$

$$\frac{1}{8}\Delta=p^{12}(1-p)^{12}\ \text{al } \bar{1}\cdot2406443$$

$$\left(\frac{1}{8}\Delta\right)^{12}=p(1-p) \qquad \text{al } \bar{1}\cdot9367280$$

The cubic for the parameter p is here

$$\xi=\frac{-1-3p+6p^2-p^3}{p(1-p)},\ x+3=\xi+6=p+\frac{1}{1-p}+\frac{p-1}{p},$$

$$x+\frac{3}{2}=-\frac{1+p\,.\,2-p\,.\,1-2p}{p(1-p)}=-\frac{3\sqrt{3}}{2}\cot 3\theta$$

$$\frac{3\sqrt{3}}{2}\cot 3\theta=\frac{1+p\,.\,2-p\,.\,1-2p}{p(1-p)} \quad =-x-\frac{3}{2}=-4\cdot550705\ \ldots.$$

from which $\cot(180^\circ-3\theta)=\text{al } 0\cdot2434268$

$$\therefore\ 3\theta=180^\circ-29^\circ\ 43'\ 22''\cdot06$$

$$\theta=50^\circ\ 5'\ 32''\cdot65$$

$$p=\frac{\sin\theta}{\sin(60+\theta)} \qquad =\text{al } \bar{1}\cdot9121104=0\cdot8167900$$

$$\frac{1}{1-p}=\frac{\sin(60+\theta)}{\sin(120+\theta)} \qquad =\text{al } 0\cdot7370511=5\cdot4582210$$

$$-\frac{p-1}{p}=-\frac{\sin(120+\theta)}{\sin(180+\theta)} \qquad =\text{al } \bar{1}\cdot3508385=0\cdot2248048$$

$$\mathrm{A}(2r)=\left[\frac{1}{8}\left(x^3-27\right)\right]^{\frac{1}{12}}\ p^{\frac{2}{3}}(1-p)^{\frac{5}{3}}(1-p+p^2)^{-\frac{1}{3}}$$

$$\left[\frac{1}{8}\left(x^3-27\right)\right]^{\frac{1}{12}}=\text{al } 1\cdot9367204$$

$$p^{\frac{2}{9}} = \text{al } \bar{1}\cdot 9804690$$

$$(1-p)^{\frac{5}{9}} = \text{al } \bar{1}\cdot 5905271$$

$$(1-p+p^2)^{-\frac{1}{3}} = \text{al } 0\cdot 0234665$$

$$A(2r) = \text{al } \bar{1}\cdot 5311830 = 0\cdot 3397634 = A(20)$$

$$\frac{A(4r)}{A(2r)} = \lambda^{-\frac{1}{3}} = p^{-\frac{1}{3}}\left(1-p\right)^{-\frac{1}{3}}$$

$$= \text{al } 0\cdot 2749802$$

$$A(4r) = \text{al } \bar{1}\cdot 8061632 = 0\cdot 6399753 = A(40)$$

$A(6r) = A(60)$, given already in trisection.

$$\frac{A(8r)}{A(2r)} = \lambda^{-\frac{1}{9}}y = p^{\frac{1}{3}}\left(1-p\right)^{-\frac{2}{3}}$$

$$= \text{al } 0\cdot 4620709$$

$$A(8r) = \text{al } \bar{1}\cdot 9932539 = 0\cdot 9845866 = A(80)$$

$$y = p^{\gamma}(1-p) = \text{al } \bar{1}\cdot 8242208$$

$$-0\cdot 7370511$$

$$= \text{al } \bar{1}\cdot 0871697 = 0\cdot 1222277$$

$$\lambda = z = p(1-p) = \text{al } \bar{1}\cdot 9121104$$

$$-0\cdot 7370511$$

$$= \bar{1}\cdot 1750593 = 0\cdot 1496440$$

$$1-p+p^2 = 1-\lambda = \text{al } \bar{1}\cdot 9296008 = 0\cdot 8503560$$

$$x = \text{al } \bar{1}\cdot 0167705 = 0\cdot 1039370$$

$$1+y = \text{al } 0\cdot 0500810 = 1\cdot 1222277$$

$$(1+y)^2 = \text{al } 0\cdot 1001620$$

$$4 = \text{al } 0\cdot 6020600$$

$$2P_1+P_2 = \frac{1}{4}\left(1+y\right)^2 = \text{al } \bar{1}\cdot 4981020 = 0\cdot 3148488$$

$$P_1-P_2 = x = 0\cdot 1039370$$

$$3P_1 = 0\cdot 4187858, \qquad P_1 = 0\cdot 1395953;$$

$$P_2 = P_1-x = 0\cdot 0356583;$$

$$P_4 = P_1-z(1-z) = 0\cdot 0123447.$$

$$C(2r)^2 = \text{al } 0\cdot 1341924$$

$$C(20) = C(2r) = \text{al } 0\cdot 0670962 = 1\cdot 1670680$$

$$\frac{C(4r)^2}{C(2r)^2}=\lambda^{-\frac{2}{3}}\frac{P_2}{P_1}$$

$$=\text{al } \bar{1}\cdot 9572505$$

$$C(4r)^2=\text{al } 0\cdot 0914429$$

$$C(40)=C(4r)=\text{al } 0\cdot 0457214=1\cdot 1110187$$

$$\frac{C(80)^2}{C(20)^2}=\lambda^{-\frac{10}{3}}y^2\frac{P_4}{P_1}$$

$$=\text{al } \bar{1}\cdot 8707515$$

$$C(80)^2=\text{al } 0\cdot 00496439$$

$$C(80)=\text{al } 0\cdot 0024719=1\cdot 005708$$

As a check on the A values, the product

$$A(20)\ A(40)\ A(80)=\left(\frac{4}{27}\sin^2 38\right)^{\frac{1}{3}}\left(\frac{x^3-27}{8}\right)^{\frac{1}{4}}=\left(\frac{x-3}{8}\right)^{\frac{1}{3}}\left(\frac{x^3-27}{8}\right)^{\frac{1}{12}}$$

Where $x=3\cdot 05070502\ \ldots$,

$$x^3-27=1\cdot 3923048454=\text{al } 0\cdot 3305999\ ;$$

and thus

$$A(20)\ A(40)\ A(80)=\text{al } \bar{1}\cdot 3306001,$$

in agreement with the calculations above.

Lemniscate Five Section, again.

8. A return can be made to Five Section in this method of the First Stage, as in *Phil. Trans.* 1904, p. 229; there with

$$\gamma_5=0,\ y=x,\ \lambda=\frac{\gamma_3}{\gamma_2}=x^{\frac{1}{3}},$$

and the modular equation

$$J : J-1 : 1=(\tau^2-10\tau+5)^3 : (\tau^2-22\tau+125)\,(\tau^2-4\tau-1)^2 : -1728\tau,$$

$$J=1,\ \tau^2-4\tau-1=0,\ \tau=2-\sqrt{5},\ \frac{1}{x}-x=11-\tau=9+\sqrt{5}=8+4\sin 54$$

$$\frac{1}{x}+x=12\sin 72°$$

$$x=6\sin 72-4-2\sin 54°$$

$$=16\sin^2 9\sin 39°\sin 51°=\text{al}\,\bar{2}\cdot 9459\ \ .\ .\ .\ .$$

$$\Delta=-x^6\tau=x^6(\sqrt{5}-2)=x^6(2\sin 18)^3$$

$$\left(\frac{1}{8}\Delta\right)^{\frac{1}{12}}=x^{\frac{1}{2}}\sin^{\frac{1}{4}}18°.$$

$$\mathrm{A}(2r)=x^{-\frac{1}{3}}\lambda^{-\frac{1}{5}}\left(\frac{1}{8}\Delta\right)^{\frac{1}{12}}=x^{\frac{1}{10}}\left(\sin 18\right)^{\frac{1}{4}}$$

$$x^{\frac{1}{10}}=\text{al}\,\bar{1}\cdot 89459\ \ .\ .\ .$$

$$(\sin 18)^{\frac{1}{4}}=\text{al}\,\bar{1}\cdot 87250\ \ .\ .\ .$$

$$\mathrm{A}(2r)=\text{al}\,1\cdot 76709\ \ .\ .\ .\ =0\cdot 5849\ \ .\ .\ .\ =\mathrm{A}(36)$$

$$\frac{\mathrm{A}(4r)}{\mathrm{A}(2r)}=x^{-\frac{1}{5}}=\text{al}\,0\cdot 2108\ \ .\ .\ .$$

$$\mathrm{A}(2r)\quad=\text{al}\,1\cdot 7671$$

$$\mathrm{A}(4r)\quad=\text{al}\,\bar{1}\cdot 9779=0\cdot 95\ \ .\ .\ .\ .\ .\ .\ =\mathrm{A}(72)$$

$$\mathrm{cl}^2\tfrac{3}{5}\ \mathrm{L}=\frac{\frac{1}{2}\Delta^{\frac{1}{6}}}{\frac{1}{12}\left[(1+x)^2+4x\right]}=\frac{\frac{1}{2}x(2\sin 18°)^{\frac{1}{2}}}{\frac{1}{12}x\left(\frac{1}{x}+x+6\right)}=\frac{\frac{1}{2}(2\sin 18)^{\frac{1}{2}}}{\sin 72+\frac{1}{2}}$$

$$=\frac{\frac{1}{2}\left(2\sin 18°\right)^{\frac{1}{2}}}{2\sin 51°\sin 69°}=\frac{\sin^3 45°\,(\sin 18°)^{\frac{1}{2}}}{\sin 51°\sin 69°}$$

$$=\ .\ .\ .\ =\text{al}\,\bar{1}\cdot 7164\ \ .\ .\ .\ =\cos 58°.6=\cos\phi(54)$$

$$\mathrm{cl}^2\tfrac{1}{5}\,\mathrm{L}=\frac{\frac{1}{2}\Delta^{\frac{1}{6}}}{\frac{1}{12}\left[(1+x)^2-8x\right]}=\frac{\frac{1}{2}(\sin 18)^{\frac{1}{2}}}{\sin 72-\sin 30}=\frac{\sin^3 45(\sin 18)^{\frac{1}{2}}}{\sin 39\sin 21}$$

$$=\quad .\ .\ .\qquad =\mathrm{al}\ \bar{1}\cdot 9702\qquad =\cos 21^\circ=\cos\phi(18).$$

So also for C(36) and C(72).

$$\mathrm{C}(2r)^2=x^{-\frac{2}{3}\cdot\frac{2}{15}}\sqrt{2}\,\frac{1+6x+x^2}{12}$$

$$=x^{\frac{1}{5}}\frac{\sqrt{2}}{12}\left(\frac{1}{x}+x+6\right)$$

$$=x^{\frac{1}{5}}\sqrt{2}(\sin 72+\sin 30)$$

$$=2\sqrt{2}\,x^{\frac{1}{5}}\sin 51\sin 69$$

$$=\ .\ .\ .$$

$$\mathrm{C}(2r)=\mathrm{al}\ 0\cdot 0507\ .\ .\ .\ =1\cdot 124\ .\ .\ .\ =\mathrm{C}(36)$$

$$\mathrm{C}(4r)^2=\quad 2\sqrt{2}x^{-\frac{1}{5}}\sin 39\sin 21$$

$$=\ .\ .\ .$$

$$\mathrm{C}(4r)=\mathrm{al}\ 0\cdot 00775\ .\ .\ .\ =1\cdot 018\ .\ .\ .\ =\mathrm{C}(72)$$

$$\mathrm{zs}\tfrac{2}{5}\mathrm{L}=\frac{x+3}{10\sqrt{(s_1-s_3)}}=\frac{x+3}{10x^{\frac{1}{2}}(2\sin 18)^{\frac{1}{4}}}$$

$$\mathrm{zs}\tfrac{4}{5}\mathrm{L}=\frac{-3x+1}{10\sqrt{(s_1-s_3)}}=\frac{-3x+1}{10x^{\frac{1}{2}}(2\sin 18)^{\frac{1}{4}}}$$

$$2\mathrm{zs}\tfrac{2}{5}\mathrm{L}-\mathrm{zs}\tfrac{4}{5}\mathrm{L}=\frac{\frac{1}{2}\left(\frac{1}{\sqrt{x}}+\sqrt{x}\right)}{(2\sin 18)^{\frac{1}{4}}}$$

$$\mathrm{zs}\tfrac{2}{5}\mathrm{L}+2\mathrm{zs}\tfrac{7}{5}\mathrm{L}=\frac{\frac{1}{2}\left(\frac{1}{\sqrt{x}}-\sqrt{x}\right)}{(2\sin 18)^{\frac{1}{4}}}$$

9. Table II for $\mathrm{K}=2\mathrm{K}'$, $\kappa'=(\sqrt{2}-1)^2$, is derived from the Lemniscate Table I by an application of the Quadric Transformation, using the formulas in Report 1913, p. 88, and so may be considered of equal accuracy.

Writing any function $A(r)$ as $A(rK)$, to distinguish the period and modulus, then with

$$\frac{K}{K'}=2\frac{L}{L'},\kappa'=\frac{1-\lambda}{1+\lambda},$$

these formulas may be replaced by

$$B(rK)^2\pm A(rK)^2=\sqrt{\lambda'}C(2rL),\ B(2rL),$$

$$C(rK)^2\pm D(rK)^2=\frac{2\sqrt{\lambda'}}{1-\lambda}C(2rL),\ \frac{2\lambda}{1-\lambda}B(2rL),$$

$$E(rK)\pm F(rK)=\frac{2\lambda}{1+\lambda}\ \frac{A(2rL)}{\sqrt{\lambda'}D(2rL)},\ \frac{2E(2rL)}{1+\lambda},$$

with $\lambda=\lambda'=\frac{1}{2}\sqrt{2}$ in the Lemniscate Table I.

A second application of this Quadric Transformation will give the numbers of Table III, where

$$G=4G',\ \gamma'=\left(\frac{\sqrt[4]{2}-1}{\sqrt[4]{2}+1}\right)^2=\cos 89^\circ\ 34';$$

so that the modular angle is more than half-way through the last degree of the quadrant; and to go further does not seem of practical utility, as on to $K=8K'$.

The geometry of these two Quadric Transformations is shown on the ellipse, of excentricity κ, drawn for semi-axes

$$a=50(\sqrt{2}+1)=120{\cdot}21\text{ mm},\ b=50(\sqrt{2}-1)=20{\cdot}21\text{ mm}.$$

The Quadric Transformations.

To show the relation geometrically, connecting the three Tables I, II, III, corresponding to

$$\frac{G}{2G'}=\frac{K}{K'}=2\frac{L}{L'},$$

$$\gamma=\frac{2\sqrt{\kappa}}{1+\kappa},\ \kappa,\ \lambda=\frac{1-\kappa'}{1+\kappa'},$$

the ellipse is drawn with excentricity κ, taking

$$\kappa'=(\sqrt{2}-1)^2,\ \kappa=\frac{2\sqrt[4]{2}}{\sqrt{2}+1}.$$

Then with $\phi=\mathrm{am}fK$ the minor excentric angle of a point P on the ellipse, and $\omega=\mathrm{am}\,(1-f)K$ the angle AOY of the perpendicular OY on the tangent at P, OY= a $\mathrm{dn}(1-f)K$, and the coordinates of P are a, $b\ \mathrm{sn}fK$, $b\ \mathrm{cn}fK$.

The longitude of P, perihelion and aphelion, is

$$ASP=2\ \mathrm{am}\ \frac{1}{2}(1-f)G,\ A'S'P=2\,\mathrm{am}\ \frac{1}{2}(1+f)G,$$

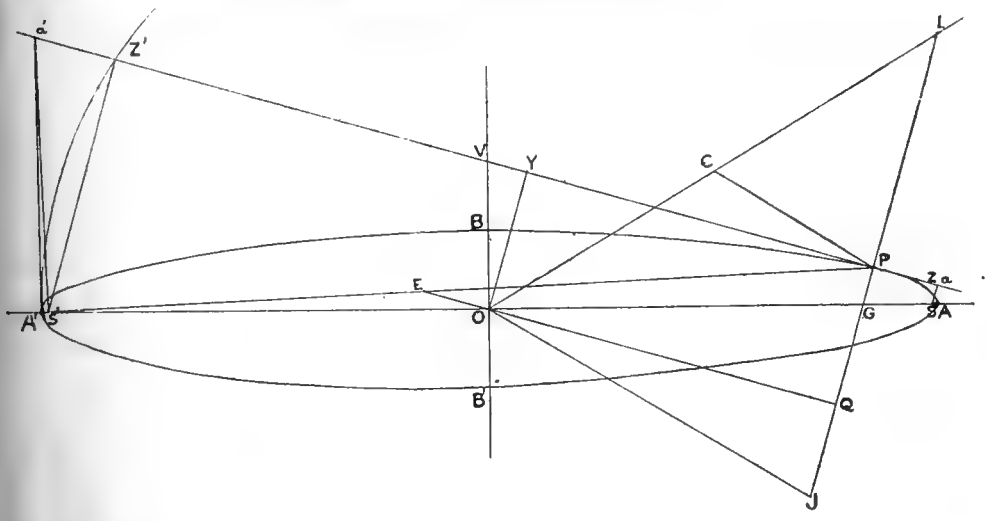
$$SZ=b\frac{\mathrm{dn}\frac{1}{2}(1-f)G}{\sqrt{\gamma'}},\quad S'Z'=b\frac{\mathrm{dn}\frac{1}{2}(1+f)G}{\sqrt{\gamma'}},$$

$$Aa=b\sqrt{\gamma'}\,\mathrm{tn}\tfrac{1}{2}(1-f)G,\quad A'a'=b\sqrt{\gamma'}\,\mathrm{tn}\tfrac{1}{2}(1+f)G,$$

$$\frac{\mathrm{dn}\frac{1}{2}(1-f)G}{\sqrt{\gamma'}}=\sqrt{\frac{1+\kappa\,\mathrm{sn}fK}{1-\kappa\,\mathrm{sn}fK}},\sqrt{\gamma'}\,\mathrm{tn}\tfrac{1}{2}(1-f)G=\sqrt{\frac{1-\mathrm{sn}fK}{1+\mathrm{sn}fK}},$$

$PQ = (a-b)\mathrm{sn}2fL$, $FJ = (a-b)\mathrm{cn}\ 2fL$, $FI = (a+b)\mathrm{dn}\ 2fL$, and $OJP=\mathrm{am}\ 2fL$, and so on, showing the geometrical interpretation of the elliptic function and its Quadric Transformations.

But the A, B, C, D functions cannot be shown in the figure; and $E(r)$, $F(r)$ arise in the rectification of the elliptic arc.



In the motion of the simple pendulum, oscillating through a finite angle, four times the modular angle, the pendulum beats the elliptic function of the time t, such that $t=\frac{1}{2}fT$, if T is the beat in seconds.

The lemniscate function is required when the pendulum swings through two right angles.

From the relation

$$\sqrt{\gamma'}\,\mathrm{tn}\tfrac{1}{2}(1-f)G=\sqrt{\frac{1-\mathrm{sn}fK}{1+\mathrm{sn}fK}}\quad\text{or}\quad\frac{\tan\phi(45+\frac{1}{2}r)G}{\tan\phi(45)G}=\tan[45-\tfrac{1}{2}\phi(rK)],$$

the column of Legendre's ϕ in Table III can be deduced from that in Table II; and so also in II from I.

A slide rule may be used in a first approximation to the nearest degree, to read off from the scale of tangents on a fixed setting of the cursor.

Elliptic Function

Table I.—*Lemniscate Function.*

K=1·8540746773=K′, E=1·3506438810=E′,

r	$F\phi$	ϕ	E(r)	D(r)	A(r)
0	0·00000 00000	0·000	0·00000 00000	1·00000 00000	0·00000 00000
1	0·02060 08297	1·180	0·00559 22185	1·00005 76114	0·01732 23240
2	0·04120 16595	2·360	0·01117 56998	1·00023 03752	0·03463 96092
3	0·06180 24892	3·540	0·01674 17286	1·00051 80814	0·05194 68175
4	0·08240 33190	4·719	0·02228 16343	1·00092 03796	0·06923 89126
5	0·10300 41487	5·896	0·02778 68123	1·00143 67802	0·08651 08611
6	0·12360 49785	7·073	0·03324 87460	1·00206 66547	0·10375 76329
7	0·14420 58082	8·248	0·03865 90273	1·00280 92364	0·12097 42023
8	0·16480 66380	9·421	0·04400 93780	1·00366 36213	0·13815 55494
9	0·18540 74677	10·593	0·04929 16689	1·00462 87696	0·15529 66598
10	0·20600 82975	11·762	0·05449 79400	1·00570 35065	0·17239 25270
11	0·22660 91272	12·929	0·05962 04166	1·00688 65237	0·18943 81524
12	0·24720 99570	14·093	0·06465 15306	1·00817 63813	0·20642 85463
13	0·26781 07867	15·254	0·06958 39334	1·00957 15091	0·22335 87294
14	0·28841 16165	16·412	0·07441 05129	1·01107 02088	0·24022 37330
15	0·30901 24462	17·567	0·07912 44078	1·01267 06562	0·25701 86008
16	0·32961 32760	18·718	0·08371 90207	1·01437 09030	0·27373 83893
17	0·35021 41057	19·866	0·08818 80301	1·01616 88793	0·29037 81691
18	0·37081 49355	21·010	0·09252 54012	1·01806 23965	0·30693 30262
19	0·39141 57652	22·150	0·09672 53955	1·02004 91494	0·32339 80622
20	0·41201 65950	23·285	0·10078 25794	1·02212 67193	0·33976 83967
21	0·43261 74247	24·416	0·10469 18308	1·02429 25769	0·35603 91671
22	0·45321 82545	25·543	0·10844 83455	1·02654 40853	0·37220 55308
23	0·47381 90842	26·664	0·11204 76417	1·02887 85035	0·38826 26656
24	0·49441 99139	27·781	0·11548 55630	1·03129 29893	0·40420 57714
25	0·51502 07437	28·893	0·11875 82813	1·03378 46028	0·42003 00711
26	0·53562 15734	30·000	0·12186 22978	1·03635 03103	0·43573 08120
27	0·55622 24032	31·101	0·12479 44426	1·03898 69880	0·45130 32670
28	0·57682 32329	32·197	0·12755 18736	1·04169 14251	0·46674 27359
29	0·59742 40627	33·288	0·13013 20757	1·04446 03288	0·48204 45468
30	0·61802 48924	34·373	0·13253 28561	1·04729 03271	0·49720 40572
31	0·63862 57222	35·451	0·13475 23413	1·05017 79739	0·51221 66556
32	0·65922 65519	36·526	0·13678 89725	1·05311 97528	0·52707 77628
33	0·67982 73817	37·594	0·13864 14993	1·05611 20812	0·54178 28334
34	0·70042 82114	38·656	0·14030 89744	1·05915 13149	0·55632 73569
35	0·72102 90412	39·712	0·14179 07457	1·06223 37524	0·57070 68597
36	0·74162 98709	40·762	0·14308 64509	1·06535 56397	0·58491 69061
37	0·76223 07007	41·806	0·14419 60059	1·06851 31742	0·59895 31001
38	0·78283 15304	42·844	0·14511 96000	1·07170 25103	0·61281 10868
39	0·80343 23602	43·874	0·14585 76849	1·07491 97630	0·62648 65539
40	0·82403 31899	44·901	0·14641 09671	1·07816 10137	0·63997 52334
41	0·84463 40197	45·921	0·14678 03964	1·08142 23139	0·65327 29030
42	0·86523 48494	46·935	0·14696 71583	1·08469 96910	0·66637 53880
43	0·88583 56792	47·942	0·14697 26631	1·08798 91523	0·67927 85625
44	0·90643 65089	48·944	0·14679 85365	1·09128 66907	0·69197 83514
45	0·92703 73387	49·940	0·14644 66094	1·09458 82886	0·70447 07318
$90-r$	F(ψ)	ψ	F(r)	C(r)	B(r)

TABLE. $\theta=45°$.

$K=K'=L$, $\kappa=\kappa'=\frac{1}{\sqrt{2}}$.

$q=e^{-\pi}=0{\cdot}04321391826377$

B(r)	C(r)	F(r)	ψ	$F(\psi)$	$90-r$
1·00000 00000	1·18920 71150	0·00000 00000	90·000	1·85407 46773	90
0·99984 54246	1·18914 94665	0·00470 60108	89·165	1·83347 38476	89
0·99938 17514	1·18897 65912	0·00940 76502	88·330	1·81287 30178	88
0·99860 91406	1·18868 87000	0·01410 05467	87·495	1·79227 21881	87
0·99752 78584	1·18828 61440	0·01878 03289	86·659	1·77167 13583	86
0·99613 82775	1·18776 94140	0·02344 26255	85·823	1·75107 05286	85
0·99444 08767	1·18713 91403	0·02808 30653	84·986	1·73046 96988	84
0·99243 62407	1·18639 60914	0·03269 72774	84·147	1·70986 88691	83
0·99012 50593	1·18554 11736	0·03728 08916	83·308	1·68926 80393	82
0·98750 81276	1·18457 54293	0·04182 95382	82·467	1·66866 72096	81
0·98458 63450	1·18350 00363	0·04633 88487	81·624	1·64806 63798	80
0·98136 07151	1·18231 63059	0·05080 44575	80·780	1·62746 55501	79
0·97783 23446	1·18102 56817	0·05522 19994	79·934	1·60686 47203	78
0·97400 24430	1·17962 97376	0·05958 71139	79·085	1·58626 38906	77
0·96987 23216	1·17813 01756	0·06389 54439	78·235	1·56566 30608	76
0·96544 33929	1·17652 88244	0·06814 26379	77·382	1·54506 22311	75
0·96071 71696	1·17482 76366	0·07232 43506	76·526	1·52446 14013	74
0·95569 52639	1·17302 86866	0·07643 62449	75·667	1·50386 05716	73
0·95037 93863	1·17113 41680	0·08047 39933	74·806	1·48325 97418	72
0·94477 13447	1·16914 63907	0·08443 32799	73·942	1·46265 89121	71
0·93887 30433	1·16706 77783	0·08830 98027	73·074	1·44205 80823	70
0·93268 64814	1·16490 08653	0·09209 92756	72·203	1·42145 72526	69
0·92621 37526	1·16264 82937	0·09579 74315	71·329	1·40085 64228	68
0·91945 70430	1·16031 28097	0·09940 00252	70·450	1·38025 55931	67
0·91241 86305	1·15789 72608	0·10290 28362	69·568	1·35965 47634	66
0·90510 08831	1·15540 45920	0·10630 16727	68·682	1·33905 39336	65
0·89750 62579	1·15283 78419	0·10959 23752	67·792	1·31845 31039	64
0·88963 72995	1·15020 01398	0·11277 08206	66·898	1·29785 22741	63
0·88149 66386	1·14749 47011	0·11583 29266	65·999	1·27725 14444	62
0·87308 69906	1·14472 48239	0·11877 46567	65·096	1·25665 06146	61
0·86441 11542	1·14189 38846	0·12159 20252	64·188	1·23604 97849	60
0·85547 20099	1·13900 53339	0·12428 11025	63·275	1·21544 89551	59
0·84627 25182	1·13606 26928	0·12683 80211	62·359	1·19484 81254	58
0·83681 57184	1·13306 95480	0·12925 89815	61·435	1·17424 72956	57
0·82710 47269	1·13002 95477	0·13154 02588	60·507	1·15364 64659	56
0·81714 27355	1·12694 63970	0·13367 82099	59·574	1·13304 56361	55
0·80693 30099	1·12382 38537	0·13566 92789	58·636	1·11244 48064	54
0·79647 88881	1·12066 57231	0·13751 00077	57·692	1·09184 39766	53
0·78578 37785	1·11747 58542	0·13919 70407	56·743	1·07124 31469	52
0·77485 11587	1·11425 81342	0·14072 71344	55·788	1·05064 23171	51
0·76368 45735	1·11101 64844	0·14209 71663	54·828	1·03004 14874	50
0·75228 76332	1·10775 48548	0·14330 41415	53·862	1·00944 06576	49
0·74066 40121	1·10447 72199	0·14434 52037	52·890	0·98883 98279	48
0·72881 74469	1·10118 75735	0·14521 76436	51·913	0·96823 89981	47
0·71675 17348	1·09788 99237	0·14591 89078	50·929	0·94763 81684	46
0·70447 07318	1·09458 82886	0·14644 66094	49·940	0·92703 73387	45
A(r)	D(r)	E(r)	ϕ	$F(\phi)$	r

Table II.—Elliptic Function Table.

K=3·1651034544=2K′; E=1·0393418350;

r	$F\phi$	ϕ	E(r)	D(r)	A(r)
0	0·00000 00000	° ′ 0 0	0·00000 00000	1·00000 00000	0·00000 00000
1	0·03516 78162	2 1	0·02360 56201	1·00041 52890	0·01456 71194
2	0·07033 56323	4 2	0·04712 70168	1·00166 07060	0·02913 50336
3	0·10550 34485	6 2	0·07048 07843	1·00373 49030	0·04370 45234
4	0·14067 12646	8 2	0·09358 51350	1·00663 56333	0·05827 63405
5	0·17583 90808	10 1	0·11636 06632	1·01035 97538	0·07285 11940
6	0·21100 68970	12 0	0·13873 10806	1·01490 32269	0·08742 97360
7	0·24617 47131	13 58	0·16062 38448	1·02026 11222	0·10201 25476
8	0·28134 25293	15 55	0·18197 07731	1·02642 76205	0·11660 01256
9	0·31651 03454	17 51	0·20270 85318	1·03339 60172	0·13119 28682
10	0·35167 81616	19 45	0·22277 90541	1·04115 87266	0·14579 10626
11	0·38684 59778	21 39	0·24212 98632	1·04970 72852	0·16039 48718
12	0·42201 37939	23 31	0·26071 43027	1·05903 23605	0·17500 43219
13	0·45718 16101	25 21	0·27849 16735	1·06912 37540	0·18961 92905
14	0·49234 94262	27 10	0·29542 72842	1·07997 04090	0·20423 94944
15	0·52751 72424	28 57	0·31149 24171	1·09156 04191	0·21886 44785
16	0·56268 50586	30 42	0·32666 42186	1·10388 10347	0·23349 36056
17	0·59785 28747	32 26	0·34092 55218	1·11691 86724	0·24812 60455
18	0·63302 06909	34 8	0·35426 46104	1·13065 89258	0·26276 07658
19	0·66818 85070	35 48	0·36667 49334	1·14508 65738	0·27739 65226
20	0·70335 63232	37 25	0·37815 47792	1·16018 55937	0·29203 18523
21	0·73852 41394	39 1	0·38870 69215	1·17593 91716	0·30666 50639
22	0·77369 19555	40 35	0·39833 82422	1·19232 97163	0·32129 42316
23	0·80885 97717	42 7	0·40705 93432	1·20933 88725	0·33591 71882
24	0·84402 75878	43 36	0·41488 41519	1·22694 75354	0·35053 15206
25	0·87919 54040	45 4	0·42182 95296	1·24513 58656	0·36513 45630
26	0·91436 32202	46 30	0·42791 48870	1·26388 33062	0·37972 33943
27	0·94953 10363	47 53	0·43316 18134	1·28316 86000	0·39429 48341
28	0·98469 88525	49 15	0·43759 37213	1·30296 98066	0·40884 54396
29	1·01986 66686	50 34	0·44123 55115	1·32326 43235	0·42337 15048
30	1·05503 44848	51 52	0·44411 32602	1·34402 89037	0·43786 90584
31	1·09020 23010	53 7	0·44625 39305	1·36523 96792	0·45233 38641
32	1·12537 01171	54 20	0·44768 51059	1·38687 21817	0·46676 14214
33	1·16053 79333	55 32	0·44843 47531	1·40890 13667	0·48114 69663
34	1·19570 57494	56 42	0·44853 10050	1·43130 16359	0·49548 54745
35	1·23087 35656	57 49	0·44800 19712	1·45404 68644	0·50977 16634
36	1·26604 13818	58 55	0·44687 55682	1·47711 04260	0·52399 99970
37	1·30120 91979	60 1	0·44517 93763	1·50046 52195	0·53816 46898
38	1·33637 70141	61 1	0·44294 05137	1·52408 36987	0·55225 97131
39	1·37154 48302	62 2	0·44018 55303	1·54793 78991	0·56627 88000
40	1·40671 26464	63 1	0·43694 03214	1·57199 94709	0·58021 54542
41	1·44188 04626	63 57	0·43323 00554	1·59623 97068	0·59406 29564
42	1·47704 82787	64 53	0·42907 91183	1·62062 95774	0·60781 43734
43	1·51221 60949	65 47	0·42451 10688	1·64513 97610	0·62146 25679
44	1·54738 39110	66 39	0·41954 86092	1·66974 06801	0·63500 02078
45	1·58255 17272	67 30	0·41421 35624	1·69440 25335	0·64841 97773
90—r	F(ψ)	ψ	F(r)	C(r)	B(r)

$K=2K'$. $\kappa'=(\sqrt{2}-1)^2$. $\theta=80°7'14''{\cdot}58$.

$E'=1{\cdot}5591717446$; $q=e^{-\frac{1}{2}\pi}=0{\cdot}207879576350762$.

B(r)	C(r)	F(r)	ψ	$F\psi$	$90-r$
1·00000 00000	2·41421 35624	0·00000 00000	90° 0′	3·16510 34544	90
0·99979 69556	2·41376 73268	0·01051 24733	89 39	3·12993 56382	89
0·99918 80246	2·41242 92194	0·02102 24584	89 19	3·09476 78221	88
0·99817 38136	2·41020 10412	0·03152 74554	88 58	3·05960 00059	87
0·99675 53317	2·40708 57883	0·04202 49414	88 37	3·02443 21898	86
0·99493 39885	2·40308 76487	0·05251 23580	88 16	2·98926 43736	85
0·99271 15912	2·39821 19957	0·06298 71010	87 55	2·95409 65574	84
0·99009 03401	2·39246 53776	0·07344 65063	87 33	2·91892 87413	83
0·98707 28236	2·38585 55074	0·08388 78393	87 12	2·88376 09251	82
0·98366 20127	2·37839 12498	0·09430 82815	86 50	2·84859 31090	81
0·97986 12540	2·37008 26067	0·10470 49177	86 28	2·81342 52928	80
0·97567 42629	2·36094 07003	0·11507 47232	86 6	2·77825 74766	79
0·97110 51144	2·35097 77549	0·12541 45496	85 44	2·74308 96605	78
0·96615 82342	2·34020 70768	0·13572 11109	85 21	2·70792 18443	77
0·96083 83890	2·32864 30309	0·14599 09689	84 58	2·67275 40282	76
0·95515 06763	2·31630 10195	0·15622 05178	84 35	2·63758 62120	75
0·94910 05121	2·30319 74557	0·16640 59688	84 11	2·60241 83958	74
0·94269 36200	2·28934 97370	0·17654 33333	83 47	2·56725 05797	73
0·93593 60181	2·27477 62174	0·18662 84057	83 22	2·53208 27635	72
0·92883 40053	2·25949 61767	0·19665 67464	82 57	2·49691 49474	71
0·92139 41482	2·24352 97905	0·20662 36615	82 31	2·46174 71312	70
0·91362 32667	2·22689 80986	0·21652 41853	82 5	2·42657 93150	69
0·90552 84193	2·20962 29703	0·22635 30587	81 42	2·39141 14989	68
0·89711 68870	2·19172 70703	0·23610 47089	81 11	2·35624 36827	67
0·88839 61588	2·17323 38239	0·24577 32266	80 43	2·32107 58666	66
0·87937 39151	2·15416 73798	0·25535 23439	80 14	2·28590 80504	65
0·87005 80112	2·13455 25727	0·26483 54098	79 46	2·25074 02342	64
0·86045 64616	2·11441 48863	0·27421 53662	79 15	2·21557 24181	63
0·85057 74217	2·09378 04130	0·28348 47221	78 44	2·18040 46019	62
0·84042 91725	2·07267 58157	0·29263 55265	78 13	2·14523 67858	61
0·83002 01019	2·05112 82872	0·30165 93417	77 40	2·11006 89696	60
0·81935 86887	2·02916 55104	0·31054 72156	77 7	2·07490 11534	59
0·80845 34845	2·00681 56171	0·31928 96518	76 33	2·03973 33373	58
0·79731 30970	1·98410 71472	0·32787 65814	75 58	2·00456 55211	57
0·78594 61725	1·96106 90080	0·33629 73328	75 22	1·96939 77050	56
0·77436 13791	1·93773 04319	0·34454 06018	74 45	1·93422 98888	55
0·76256 73892	1·91412 09366	0·35259 44205	74 7	1·89906 20726	54
0·75057 28631	1·89027 02821	0·36044 61289	73 28	1·86389 42565	53
0·73838 64325	1·86620 84313	0·36808 23448	72 47	1·82872 64403	52
0·72601 66842	1·84196 55077	0·37548 89337	72 6	1·79355 86242	51
0·71347 21440	1·81757 17564	0·38265 09832	71 23	1·75839 08080	50
0·70076 12613	1·79305 75014	0·38955 27740	70 39	1·72322 29918	49
0·68789 23937	1·76845 31081	0·39617 77607	69 54	1·68805 51757	48
0·67487 37926	1·74378 89429	0·40250 85448	69 7	1·65288 73595	47
0·66171 35884	1·71909 53339	0·40852 68614	68 19	1·61771 95434	46
0·64841 97773	1·69440 25335	0·41421 35624	67 30	1·58255 17272	45
A(r)	D(r)	E(r)	ϕ	F(ϕ)	r

Table III.—Elliptic Function

$K=4K'=6{\cdot}28327\ 29540$ $E=1{\cdot}00016\ 13425$ $E'=1{\cdot}57077\ 44156$

r	$F\phi$	ϕ	E(r)	D(r)	A(r)
0	0·00000 00000	° ′ 0 0	0·00000 00000	1·00000 00000	0·00000 00000
1	0·06981 41439	4 0	0·05858 80421	1·00204 92085	0·00603 64042
2	0·13962 82879	7 58	0·11650 21507	1·00819 82674	0·01208 81679
3	0·20944 24318	11 55	0·17309 42086	1·01845 14653	0·01817 06193
4	0·27925 65757	15 48	0·22776 56568	1·03281 58868	0·02429 90271
5	0·34907 07196	19 36	0·27998 73710	1·05130 13277	0·03048 85680
6	0·41888 48636	23 20	0·32931 43867	1·07392 01702	0·03675 42965
7	0·48869 90075	26 57	0·37539 48102	1·10068 72231	0·04311 11140
8	0·55851 31514	30 27	0·41797 29107	1·13161 95325	0·04957 37375
9	0·62832 72954	33 51	0·45688 69337	1·16673 61537	0·05615 66670
10	0·69814 14393	37 6	0·49206 25794	1·20605 78963	0·06285 41547
11	0·76795 55832	40 13	0·52350 33154	1·24960 70304	0·06974 01705
12	0·83776 97272	43 12	0·55127 87232	1·29740 69731	0·07676 83701
13	0·90758 38711	46 3	0·57551 19971	1·34948 19370	0·08397 20607
14	0·97739 80150	48 46	0·59636 75185	1·40585 65533	0·09136 41666
15	1·04721 21590	51 19	0·61403 92034	1·46655 54743	0·09895 71948
16	1·11702 63029	53 46	0·62874 00873	1·53160 29461	0·10676 31990
17	1·18684 04468	56 3	0·64069 34062	1·60102 23549	0·11479 37439
18	1·25665 45908	58 14	0·65012 52555	1·67483 57686	0·12305 98692
19	1·32646 87347	60 16	0·65725 87889	1·75306 34391	0·13157 20525
20	1·39628 28787	62 12	0·66230 98356	1·83572 32845	0·14034 01725
21	1·46609 70226	64 0	0·66548 37561	1·92283 04806	0·14937 34717
22	1·53591 11665	65 42	0·66697 33531	2·01439 67047	0·15868 05185
23	1·60572 53104	67 18	0·66695 76408	2·11042 98279	0·16826 91705
24	1·67553 94544	68 48	0·66560 12877	2·21093 32570	0·17814 65368
25	1·74535 35983	70 12	0·66305 45812	2·31590 54054	0·18831 89404
26	1·81516 77422	71 30	0·65945 37698	2·42533 91499	0·19879 18825
27	1·88498 18862	72 44	0·65492 16739	2·53922 12848	0·20957 00058
28	1·95479 60301	73 53	0·64956 84700	2·65753 19744	0·22065 70585
29	2·02461 01740	74 57	0·64349 25792	2·78024 42315	0·23205 58614
30	2·09442 43180	75 58	0·63678 16067	2·90732 33850	0·24376 82728
31	2·16423 84619	76 54	0·62951 32880	3·03872 65788	0·25579 51579
32	2·23405 26058	77 47	0·62175 64169	3·17440 22854	0·26813 63574
33	2·30386 67498	78 36	0·61357 17327	3·31428 98349	0·28079 06595
34	2·37368 08937	79 21	0·60501 27571	3·45831 89676	0·29375 57725
35	2·44349 50376	80 5	0·59612 65692	3·60640 94238	0·30702 83011
36	2·51330 91816	80 45	0·58695 45195	3·75847 05548	0·32060 37240
37	2·58312 33255	81 22	0·57753 28798	3·91440 09654	0·33447 63744
38	2·65293 74694	81 57	0·56789 34314	4·07408 82075	0·34863 94241
39	2·72275 16133	82 29	0·55806 39922	4·23740 84869	0·36308 48693
40	2·79256 57573	83 0	0·54806 88926	4·40422 64464	0·37780 35221
41	2·86237 99012	83 28	0·53792 93957	4·57439 49541	0·39278 50021
42	2·93219 40452	83 54	0·52766 40718	4·74775 49776	0·40801 77356
43	3·00200 81891	84 19	0·51728 91320	4·92413 54739	0·42348 89556
44	3·07182 23330	84 42	0·50681 87187	5·10335 33598	0·43918 47081
45	3·14163 64770	85 4	0·49626 51667	5·28521 35079	0·45508 98606
$90-r$	F(ψ)	ψ	F(r)	C(r)	B(r)

TABLE. G=4G′, $\theta=89°34'19''\cdot25$.

$q=e^{-\frac{\pi}{4}}=0\cdot45593\ 81277\ 65996$ $\kappa'=\left(\frac{\sqrt[4]{2}-1}{\sqrt[4]{2}+1}\right)^2=0\cdot00746\ 96667\ 29510$

(Br)	C(r)	F(r)	ψ	$F\psi$	90−r
1·00000 00000	11·57042 70157	0·00000 00000	90° 0′	6·28327 29540	90
0·99961 21582	11·56594 10742	0·01110 90021	89 59	6·21345 88100	89
0·99844 95255	11·55249 36903	0·02221 79661	89 57	6·14364 46661	88
0·99651 48079	11·53011 61748	0·03332 68530	89 55	6·07383 05221	87
0·99381 24905	11·49886 05646	0·04443 56226	89 53	6·00401 63782	86
0·99034 88308	11·45879 94288	0·05554 42316	89 51	5·93420 22343	85
0·98613 18332	11·41022 56023	0·06665 26351	89 49	5·86438 80903	84
0·98117 12170	11·35265 18136	0·07776 07826	89 47	5·79457 39464	83
0·97547 83788	11·28681 02299	0·08886 86193	89 45	5·72475 98025	82
0·96906 63493	11·21265 20961	0·09997 60847	89 43	5·65494 56586	81
0·96194 97426	11·13034 68769	0·11108 31100	89 41	5·58513 15146	80
0·95414 47008	11·04008 19014	0·12218 96192	89 38	5·51531 73707	79
0·94566 88326	10·94206 15129	0·13329 55250	89 36	5·44550 32267	78
0·93654 11461	10·83650 63340	0·14440 07287	89 33	5·37568 90828	77
0·92678 19770	10·72365 24380	0·15550 51181	89 31	5·30587 49389	76
0·91641 29136	10·60375 04891	0·16660 85650	89 28	5·23606 07949	75
0·90545 67162	10·47706 48340	0·17771 09231	89 25	5·16624 66510	74
0·89393 72325	10·34387 25033	0·18881 20240	89 22	5·09643 25071	73
0·88187 93117	10·20446 22560	0·19991 16757	89 18	5·02661 83632	72
0·86930 87124	10·05913 35212	0·21100 96573	89 15	4·95680 42192	71
0·85625 20119	9·90819 53545	0·22210 57156	89 11	4·88699 00753	70
0·84273 65113	9·75196 53632	0·23319 95599	89 7	4·81717 59313	69
0·82879 01396	9·59076 86075	0·24429 08557	89 3	4·74736 17874	68
0·81444 13555	9·42493 64896	0·25537 92198	88 59	4·67754 76435	67
0·79971 90518	9·25480 56616	0·26646 42111	88 54	4·60773 34995	66
0·78465 24565	9·08071 69028	0·27754 53228	88 49	4·53791 93556	65
0·76927 10350	8·90301 40169	0·28862 19726	88 43	4·46810 52117	64
0·75360 43950	8·72204 27514	0·29969 34905	88 37	4·39829 10678	63
0·73768 21889	8·53814 96983	0·31075 91082	88 31	4·32847 69238	62
0·72153 40215	8·35168 12558	0·32181 79402	88 24	4·25866 27799	61
0·70518 93568	8·16298 25852	0·33286 89701	88 17	4·18884 86360	60
0·68867 74299	7·97239 66050	0·34391 10296	88 10	4·11903 44920	59
0·67202 71576	7·78026 30340	0·35494 27749	88 1	4·04922 03481	58
0·65526 70562	7·58691 74407	0·36596 26621	87 53	3·97940 62041	57
0·63842 51604	7·39269 03659	0·37696 89165	87 43	3·90959 20602	56
0·62152 89454	7·19790 64627	0·38795 94978	87 33	3·83977 79163	55
0·60460 52544	7·00288 37071	0·39893 20617	87 23	3·76996 37724	54
0·58768 02283	6·80793 26319	0·40988 39140	87 11	3·70014 96284	53
0·57077 92414	6·61335 56443	0·42081 19586	86 59	3·63033 54845	52
0·55392 64801	6·41944 63701	0·43171 26378	86 45	3·56052 13406	51
0·53714 66874	6·22648 90707	0·44258 18640	86 31	3·49070 71966	50
0·52046 15100	6·03475 81051	0·45341 49423	86 16	3·42089 30527	49
0·50389 30526	5·84451 74622	0·46420 64782	86 0	3·35107 89087	48
0·48746 20355	5·65602 03474	0·47495 02782	85 42	3·28126 47648	47
0·47118 81168	5·46950 88405	0·48563 92289	85 24	3·21145 06209	46
0·45508 98606	5·28521 35079	0·49626 51667	85 4	3·14163 64770	45
A(r)	D(r)	E(r)	ϕ	Fϕ	r

Table IV.

Powers of $e^{-\pi}$.

$e^{-\frac{\pi}{16}}$	$10^{-1}\times$	8·21724 95803 38771 82647	$e^{-\frac{23\pi}{4}}$	$10^{-8}\times$	1·42835 43620 24819 2288
$e^{-\frac{\pi}{8}}$	$10^{-1}\times$	6·75231 90665 57772 17032	$e^{-6\pi}$	$10^{-9}\times$	6·51241 21360 79900 72742
$e^{-\frac{\pi}{4}}$	$10^{-1}\times$	4·55938 12776 59962 36766	$e^{-\frac{49\pi}{8}}$	$10^{-9}\times$	4·39738 84635 73454 24323
$e^{-\frac{\pi}{2}}$	$10^{-1}\times$	2·07879 57635 07619 08547	$e^{-\frac{25\pi}{4}}$	$10^{-9}\times$	2·96925 69965 64822 24737
$e^{-\frac{9\pi}{16}}$	$10^{-1}\times$	1·70819 83615 29299 96975	$e^{-\frac{13\pi}{2}}$	$10^{-9}\times$	1·35379 74758 69850 17545
$e^{-\frac{3\pi}{4}}$	$10^{-2}\times$	9·47802 24842 15485 27998	$e^{-\frac{27\pi}{4}}$	$10^{-10}\times$	6·17247 88652 24309 5668
$e^{-\pi}$	$10^{-2}\times$	4·32139 18263 77224 97744	$e^{-7\pi}$	$10^{-10}\times$	2·81426 84574 85552 72075
$e^{-\frac{9\pi}{8}}$	$10^{-2}\times$	2·91794 16423 31385 00211	$e^{-\frac{29\pi}{4}}$	$10^{-10}\times$	1·28313 22915 36861 08472
$e^{-\frac{5\pi}{4}}$	$10^{-2}\times$	1·97028 72986 61711 03114	$e^{-\frac{15\pi}{2}}$	$10^{-11}\times$	5·85028 93467 94089 01023
$e^{-\frac{3\pi}{2}}$	$10^{-3}\times$	8·98329 10211 29427 89031	$e^{-\frac{121\pi}{16}}$	$10^{-11}\times$	4·80732 87679 80411 54525
$e^{-\frac{25\pi}{16}}$	$10^{-3}\times$	7·38179 44373 43684 83924	$e^{-\frac{31\pi}{4}}$	$10^{-11}\times$	2·66736 99716 66650 0218
$e^{-\frac{7\pi}{4}}$	$10^{-3}\times$	4·09582 48893 50835 89251	$e^{-8\pi}$	$10^{-11}\times$	1·21615 56709 40930 83836
$e^{-2\pi}$	$10^{-3}\times$	1·86744 27317 07988 81443	$e^{-\frac{33\pi}{4}}$	$10^{-12}\times$	5·54491 73968 08070 01363
$e^{-\frac{9\pi}{4}}$	$10^{-4}\times$	8·51438 34280 51580 35852	$e^{-\frac{17\pi}{2}}$	$10^{-12}\times$	2·52813 92565 17773 07965

$e^{-\frac{5\pi}{2}}$	$10^{-4}\times$	3·88203 20392 67662 48320	$e^{-\frac{35\pi}{4}}$	$10^{-12}\times$	1·15267 50793 48431 1567
$e^{-\frac{11\pi}{4}}$	$10^{-4}\times$	1·76996 64199 11310 41218	$e^{-9\pi}$	$10^{-13}\times$	5·25548 51760 06448 54966
$e^{-3\pi}$	$10^{-5}\times$	8·06995 17570 30459 92268	$e^{-\frac{37\pi}{4}}$	$10^{-13}\times$	2·39617 60716 50327 35885
$e^{-\frac{49\pi}{16}}$	$10^{-5}\times$	6·63128 07688 81268 12112	$e^{-\frac{19\pi}{2}}$	$10^{-13}\times$	1·09250 80319 05929 90845
$e^{-\frac{25\pi}{8}}$	$10^{-5}\times$	5·44908 89115 19816 85844	$e^{-\frac{39\pi}{4}}$	$10^{-14}\times$	4·98116 06663 65029 6377
$e^{-\frac{13\pi}{4}}$	$10^{-5}\times$	3·67939 86952 62379 65617	$e^{-10\pi}$	$10^{-14}\times$	2·27110 10683 24093 83627
$e^{-\frac{7\pi}{2}}$	$10^{-5}\times$	1·67757 81524 22578 70818	$e^{-\frac{81\pi}{8}}$	$10^{-14'}\times$	1·53351 99045 72450 44497
$e^{-\frac{15\pi}{4}}$	$10^{-6}\times$	7·64871 84199 66896 0034	$e^{-\frac{41\pi}{4}}$	$10^{-14}\times$	1·03548 15690 59041 24435
$e^{-4\pi}$	$10^{-6}\times$	3·48734 23562 08995 49124	$e^{-\frac{21\pi}{2}}$	$10^{-15}\times$	4·72115 52793 29754 02509
$e^{-\frac{17\pi}{4}}$	$10^{-6}\times$	1·59001 23447 68987 34604	$e^{-\frac{43\pi}{4}}$	$10^{-15}\times$	2·15255 46989 50157 0429
$e^{-\frac{9\pi}{2}}$	$10^{-7}\times$	7·24947 25159 87938 10426	$e^{-11\pi}$	$10^{-16}\times$	9·81431 75935 32322 67257
$e^{-\frac{19\pi}{4}}$	$10^{-7}\times$	3·30531 09262 30586 7213	$e^{-\frac{45\pi}{4}}$	$10^{-16}\times$	4·47472 15888 96004 85641
$e^{-5\pi}$	$10^{-7}\times$	1·50701 72753 90064 61056	$e^{-12\pi}$	$10^{-17}\times$	4·24115 11830 16077 54096
$e^{-\frac{81\pi}{16}}$	$10^{-7}\times$	1·23835 37073 76228 77483	$e^{-\frac{49\pi}{4}}$	$10^{-17}\times$	1·93370 25299 56890 45015
$e^{-\frac{21\pi}{4}}$	$10^{-8}\times$	6·87106 63505 23588 14659	$e^{-\frac{25\pi}{2}}$	$10^{-18}\times$	8·81648 71116 49148 83548
$e^{-\frac{11\pi}{2}}$	$10^{-8}\times$	3·13278 11276 13661 21471	$e^{-\frac{121\pi}{8}}$	$10^{-21}\times$	2·31104 09883 45206 15394

Table V.

Lemniscate Seven-Section.

p	$\frac{\Theta\left(\frac{pL}{7}\right)}{\Theta(0)}$	$\frac{H\left(\frac{pL}{7}\right)}{H(L)}$	p
0	1·00000 00000 00000	0·00000 00000 00000	0
1	1·00936 58229 47993	0·22129 74250 79583	1
2	1·03560 98708 92518	0·43125 77701 68692	2
3	1·07353 77726 58000	0·62064 82635 15161	3
4	1·11564 03165 97640	0·77956 54242 21669	4
5	1·15357 85775 32318	0·89970 42569 08297	5
6	1·17983 55431 49531	0·97456 79842 81221	6
7	1·18920 71150 02721	1·00000 00000 00000	7

p	$\mathrm{zn}\left(\frac{pL}{7}\right)$	$\left(\frac{pL}{7}\right)$	p
0	0·00000 00000 00000	0·00000 00000 00000	0
1	0·06888 56201 24538	0·26486 78110 43001	1
2	0·12099 28414 62009	0·52973 56220 86002	2
3	0·14556 40387 29594	0·79460 34331 29003	3
4	0·14009 08003 46822	1·05947 12441 72005	4
5	0·10866 34496 84876	1·32433 90552 15006	5
6	0·05896 69011 38268	1·58920 68662 58007	6
7	0·00000 00000 00000	1·85407 46773 01008	7

Table VI.

Lemniscate Seventeen-Section.

p	$\frac{\Theta\left(\frac{pL}{17}\right)}{\Theta(0)}$	$\frac{H\left(\frac{pL}{17}\right)}{H(L)}$	p
0	1·00000 00000 00000	0·00000 00000 00000	0
1	1·00161 02898 05115	0·09158 62798 43390	1
2	1·00638 63848 02693	0·18242 57702 30559	2
3	1·01416 57603 24650	0·27177 54128 50753	3
4	1·02468 37547 43416	0·35889 97495 23133	4
5	1·03758 24532 97111	0·44307 52939 95940	5
6	1·05242 28880 79385	0·52359 49017 76129	6
7	1·06869 99396 73849	0·59977 32511 86474	7
8	1·08575 95035 19737	0·67095 24177 31026	8
9	1·10331 73336 19295	0·73650 81357 50541	9
10	1·12047 89245 06076	0·79585 64012 36780	10
11	1·13675 97564 18633	0·84846 03671 08501	11
12	1·15160 52142 43612	0·89385 30966 27869	12
13	1·16450 95001 74870	0·93156 49681 79213	13
14	1·17503 28916 99758	0·96128 85747 77562	14
15	1·18281 67451 47327	0·98272 56451 55777	15
16	1·18759 57941 21283	0·99567 09714 29336	16
17	1·18920 71150 02721	1·00000 00000 00000	17

p	zn $\left(\frac{pL}{17}\right)$	$\left(\frac{pL}{17}\right)$	p
0	0·00000 00000 00000	0·00000 00000 00000	0
1	0·02939 81312 61952	0·10906 32163 11824	1
2	0·05752 18038 88374	0·21812 64326 23648	2
3	0·08318 49781 09218	0·32718 96489 35472	3
4	0·10536 59754 05873	0·43625 28652 47296	4
5	0·12326 37214 11676	0·54531 60815 59120	5
6	0·13632 86187 09034	0·65437 92978 70944	6
7	0·14425 54793 12253	0·76344 25141 82768	7
8	0·14698 97191 03705	0·87250 57304 94592	8
9	0·14467 25130 68447	0·98156 89468 06416	9
10	0·13761 35319 00651	1·09063 21631 18240	10
11	0·12625 08170 11686	1·19969 53794 30064	11
12	0·11110 23480 17156	1·30875 85957 41888	12
13	0·09275 86478 88789	1·41782 18120 53712	13
14	0·07183 58238 46666	1·52688 50283 65536	14
15	0·04897 12544 34710	1·63594 82446 77360	15
16	0·02480 99252 72634	1·74501 14609 89184	16
17	0·00000 00000 00000	1·85407 46773 01008	17

Geophysical Discussions.—Report of the Committee, consisting of Sir F. W. Dyson (*Chairman*), Dr. S. Chapman (*Secretary*), Dr. C. Chree, Colonel Sir C. F. Close, Mr. J. H. Jeans, Professor A. E. H. Love, Colonel H. G. Lyons, Professor H. F. Newall, Professor A. Schuster, Sir Napier Shaw, Sir Aubrey Strahan, Professor H. H. Turner, *and* Mr. G. W. Walker.

In accordance with the terms of reference to this Committee, 'To arrange meetings in the ensuing year for the discussion of papers and reports on Geophysical subjects, and to co-operate with existing Committees in making recommendations for the promotion of the study of such subjects in the British Empire,' the following meetings were arranged during the session 1918-19:—

1918. Nov. 19. Discussion on the Constitution of the Earth's Interior, Mr. R. D. Oldham, F.R.S.—Chairman, Major P. A. Macmahon, F.R.S.

1919. Jan. 21. Report on Seiches, Dr. E. M. Wedderburn; Tidal Motions in the Atmosphere, Major G. I. Taylor and Dr. S. Chapman.—Chairman, Sir Napier Shaw, F.R.S.

1919. Feb. 18. Report on Seismology, Prof. H. H. Turner, F.R.S.; Account of two papers by the late Prince Galitzin, Mr. G. W. Walker, F.R.S.—Chairman, Dr. A. Schuster, Sec.R.S.

1919. March 18. Discussion on the Measurement, by means of Horizontal Coils, of Pulsations in the Earth's Vertical Magnetic Force, Dr. Crichton Mitchell, Prof. W. H. Bragg,

F.R.S.; Report on a Survey of Magnetically Disturbed Localities in England, and of the Geological Significance of the Disturbances, Prof. H. Cox and Prof. E. Wilson.—Chairman, Prof. H. F. Newall, F.R.S.

1919. May 20. Discussion on the Functions of a Geodetic Institute, Col. H. G. Lyons, F.R.S., Col. Sir C. F. Close, K.B.E., F.R.S., Prof. Sir J. Larmor, M.P., F.R.S., Admiral J. F. Parry, Sir F. W. Dyson, F.R.S., and others. —Chairman, Brig.-Gen. E. H. Hills, F.R.S.

1919. June 17. Report on Atmospheric Electricity, Dr. C. T. R. Wilson, F.R.S.—Chairman, Mr. J. H. Jeans, F.R.S.

These meetings were held at 5 P.M. on the third Tuesdays of the respective months. The Royal Astronomical Society continued its hospitality by allowing the use of its rooms for the discussions and Committee meetings. The attendance at the discussions was well maintained throughout the year.

The Committee is glad to be able to report that proposals for the continuance of their work, placed before the Royal Astronomical Society, were favourably received, and that the Society has appointed a Geophysical Committee for the said purpose. The new Committee consists of twelve members, of whom five are appointed on the nomination, and as the representatives, of the following Societies, which are thus associated with the Royal Astronomical Society in the work of the Committee:—

The Royal Geographical Society.
The Royal Meteorological Society.
The Geological Society.
The Physical Society.
The British Astronomical Association.

The present Committee of the British Association, in consequence, does not ask to be reappointed.

BRITISH MUSEUM
NATURAL HISTORY

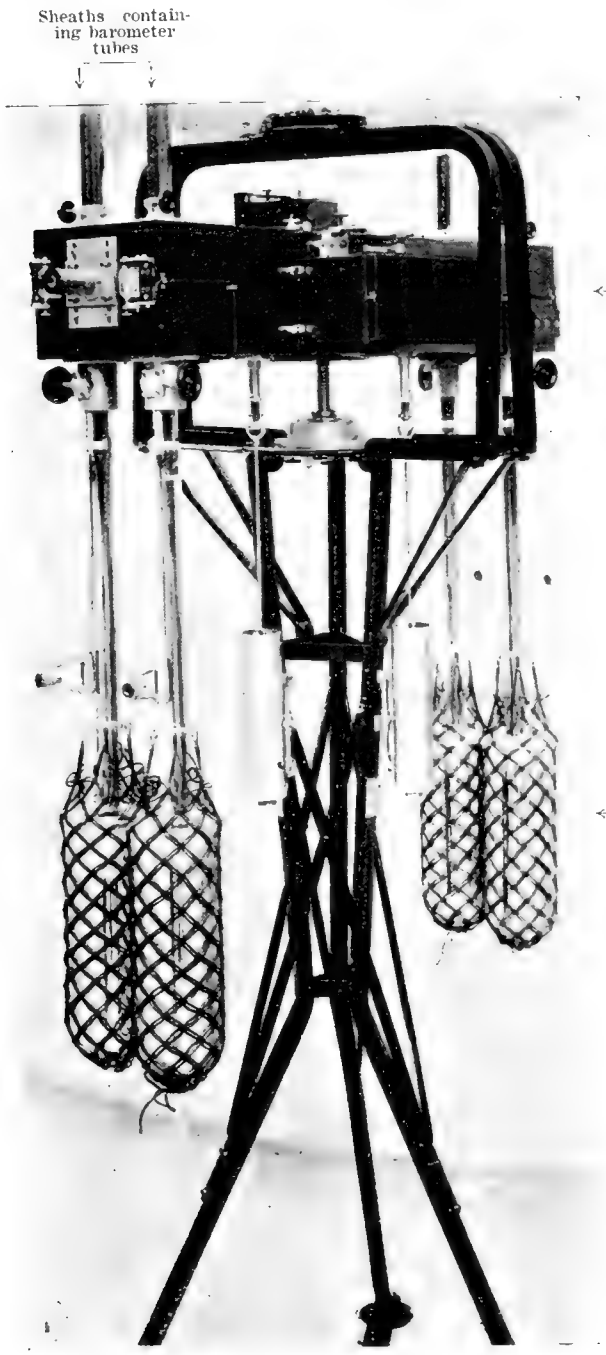


FIG. 1.
General View of Hecker's Apparatus.

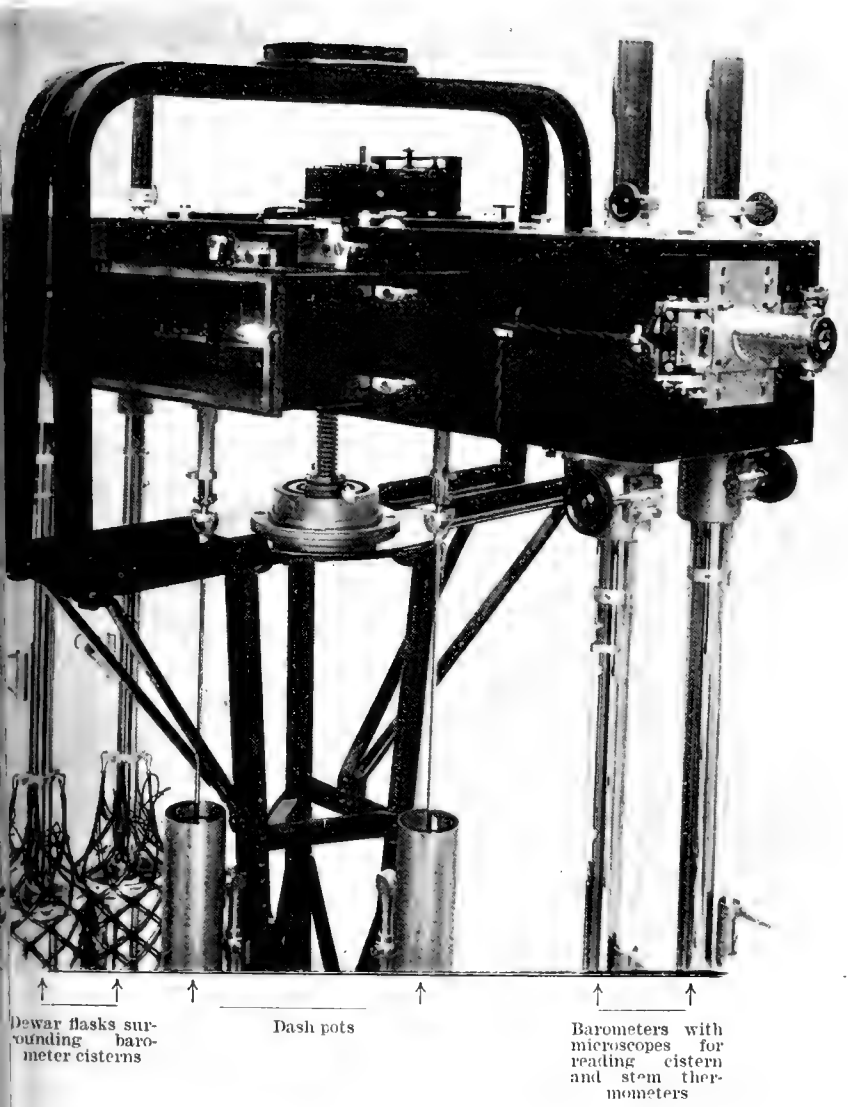


Fig. 2.
Showing the Photographic Apparatus.

BRITISH MUSEUM
NATURAL HISTORY

Determination of Gravity at Sea.—Second Report of the Committee, consisting of Professor A. E. H. Love (*Chairman*), Professor W. G. Duffield (*Secretary*), Mr. T. W. Chaundy, Sir H. Darwin, Professor A. S. Eddington, Major E. O. Henrici, Professor A. Schuster, *and* Professor H. H. Turner.

[Plates I. and II.]

I. Report upon Hecker's New Method of Measuring Gravity at Sea with Apparatus of the Enclosed Mercury Barometer Type. *By* Professor W. G. Duffield.

Two methods used by the writer in 1914, during the voyage of the British Association to Australia, have been described in *Roy. Soc. Proc. A.*, vol. xcii., p. 505, and in the British Association Report, Newcastle, 1916. It remains to discuss the third method of attack. The apparatus employed was lent to the writer in June 1914 by Professor Hecker, of Strassburg, who was anxious to have it tested at sea, and welcomed the opportunity which the voyage of the British Association afforded. Although less successful than either of the other methods employed, it will be useful to put upon record an account of the apparatus, the manner of making the experiments, and the causes of failure, in order that subsequent workers may benefit from the experience gained during the voyages.

The apparatus (fig. 1) was of the enclosed barometer type arranged for photographic records. The air sealed in the barometer cistern was maintained at as constant a temperature as possible in order that its pressure might vary but slightly during the voyage. This pressure is equal to $\rho g h$, where ρ is the density and h the height of the mercury column. It is clear that any variation in g will occasion a change in the level of the mercury, and that the column will be shorter if gravity increases and longer if it diminishes, provided that isothermal conditions are maintained; conversely, a measure of the displacement of the mercury is a measure of the change of gravity. Four similar barometers were provided, each with a constriction to prevent excessive 'pumping' of the mercury surface at sea; each was mounted in a metal sheath and provided with two thermometers, one, graduated in 0·01° C., for measuring the temperature of the air in the reservoir, and another, graduated in 1·0° C., for obtaining the stem temperature.

The barometers were mounted in pairs at the ends of a wooden light-tight box, through the centre of which passed a photographic film operated by clockwork (fig. 2). An 8-volt lamp illuminated each mercury surface and a separate lens focussed the image of each meniscus upon the moving

film, one above the other, vertical slits in the metal sheaths limiting the widths of the images to narrow lines. As the mercury pumped up and down each trace upon the moving film was bounded by a wavy line which represented the combined effect of rolling and pitching, and of the vertical motion of the ship as it rose or fell upon the ocean waves (fig. 3). The box was supported centrally on gimbals, dash pots being provided to check the swinging. The metal stand supporting the apparatus rested upon three thick felt pads to absorb as much vibration as possible and the top kept in position by ropes tied to hooks on the walls. In order to maintain as constant a temperature as possible the experiments were conducted in the refrigerating chambers of the ships upon which the voyages were made (see British Association Report, 1916), the reservoirs of the barometer being specially protected by large Dewar vessels filled with cork shavings.

Save in one respect, the whole apparatus is most beautifully constructed, and it is all superbly finished, great attention being paid to making the cabinet work light-tight, to the accuracy of the clockwork driving the film and to the focussing and adjustment of the several images upon it.

The general type of barometer tube favoured by Hecker has been described by him in volumes entitled 'Bestimmung der Schwerkraft auf dem Atlantischen Ozean' (Berlin, 1903) and 'Bestimmung der Schwerkraft auf dem Indischen und Grossen Ozean' (Berlin, 1908). They possess a larger space than usual above the mercury in the barometer tube to diminish the effect of any residual gas, since, with a fine constriction, it was not feasible to boil the mercury after it had been introduced. The constriction has symmetrical, funnel-shaped entrances. Hecker claims that this ensures equal resistance to the flow of mercury when rising and falling, and that it possesses an advantage over the Kew marine pattern in this respect. A small trap is provided to catch minute bubbles of air. All barometers are engraved with short lines at equal distances apart, which can be identified upon the films.

Method of Observation.

Before entering the small laboratory partitioned off from the main refrigerating chamber, the temperature was ascertained by extracting a thermometer which penetrated the wall, the door opened and closed behind the observer as quickly as possible, lamps illuminating the mercury surfaces switched on, heights of barometers adjusted to give the images in their proper places on the films, and sheath readings noted. The temperatures of all cistern and stem thermometers were recorded as quickly as possible, the clockwork for driving the film started, an identification mark made on the film by occulting one or other of the barometer lights a certain number of times, and the room left for fifteen to twenty minutes. At the end of this period all observations were repeated. A fan ran continuously in the refrigerator day and night. Rubber overalls were worn in the chamber, they had some effect in reducing the influence of the observer's body upon the thermometers. Three sets of observations were carried out on an average each day.

After every three or four days the exposed film was removed and

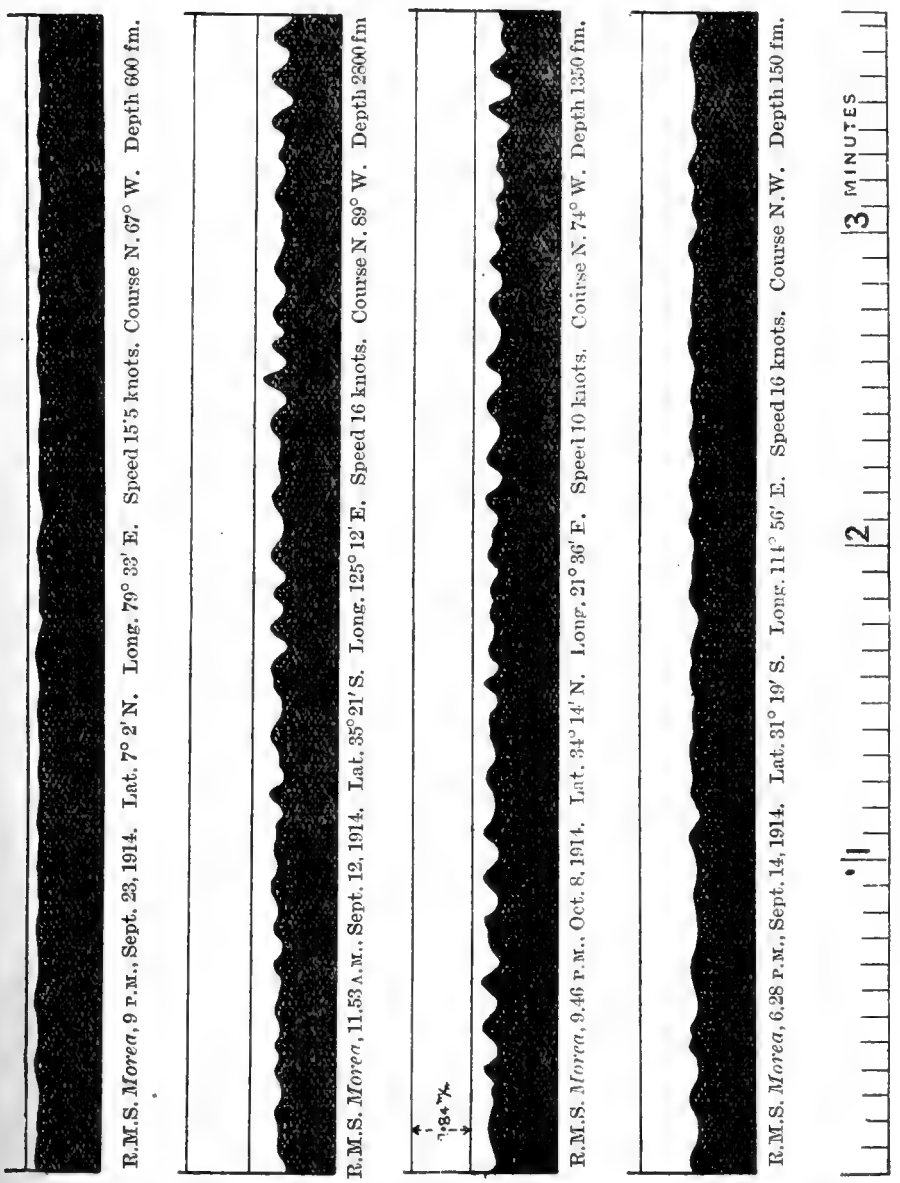


FIG. 3.

Types of records obtained with one of Hecker's self-recording enclosed barometers on four different days, showing approximate time-scale and the engraved fiducial lines, which are 2·84 mm. apart on the barometer tube. Sept. 12 and Oct. 8 were very rough days. The reproductions represent positives, hence the black portion represents the mercury in the tube. The depths are in fathoms.

developed on board ship; on the *Morea* this was done in the refrigerator, and the results are better than those obtained on the *Ascanius* when developing was carried out in a cabin. Rodinol and Eastman's cinematograph films were very satisfactory. During the voyages over 5,000 readings of the thermometers, &c., were made and 100 feet of film developed.

Reduction of Results.

A measuring machine originally constructed by Hilger for spectroscopic work and accurate to ·002 mm. was used. Each film was placed so that its length was perpendicular to the direction of travel of the micrometer eye-piece. A double thread was sighted along the line of hollows, then along the line of crests, then upon the images of the engraved lines, and finally upon the top edge of the exposed portion of the film. This was done in three different parts of each exposed strip, the results tabulated and the distances calculated.

Two errors peculiar to photographic registration have to be corrected :—

(1) The scale is engraved on the glass, and unless the ray of light passes horizontally over the curved meniscus the relative positions of mercury and scale will not be correctly shown upon the film. Assuming that the shape of the meniscus is known, the correction can be calculated for different heights of the mercury above the horizontal ray, but it is more satisfactory to find it experimentally by taking a number of photographs in harbour when the barometer is steady, thus :—the whole instrument is moved up and down, so that the mercury surface is at various heights above and below the horizontal ray, and the distances on the film of the mercury surface from one of the engraved lines are tabulated against the depth of the mercury from the top of the window through which the light passes, a distance easily calculated from measurements of the widths of the exposed band. To correct for any variations in the barometer during the test it is advisable to return to a fixed reading at frequent intervals. Experiments according to this programme were carried out in Cape Town Harbour on July 13, 1914.

The correction to the observed reading of one of Hecker's barometers is approximately ·008 mm. for a difference of 0·1 mm. in the width of the exposed strip.

(2) The brightness of the lamps, the rate of running of the film, and the time of development being variable, all developed images are not of equal blackness. The position of the boundary of this image depends to some extent upon its density, hence it is necessary to introduce a correction on this account.

This can be evaluated by taking a series of records with constant barometer with illuminations of different powers. The density of each deposit may be measured by a density meter, and the corresponding measurement of the film plotted against it. On Hartmann's scale of densities the correction varies from − 0·02 mm. for density 5 to + 0·02 mm. for density 75. The densities of the films varied over very narrow limits, so for this reason and others which will appear, these corrections were regarded as too small to merit application to any of the figures obtained,

though had conditions been more favourable they would have been taken into account.

From the dimensions of the apparatus and the coefficients of expansion of its various parts it is possible to calculate the relationship between δg and the variations in T, the temperature of the air reservoir, in t, the stem temperature, and in h, the height of the mercury column in millimetres. But, in view of the difficulty of accurate determinations of the volumes of the various parts of the barometers (though this was tried), it was considered more convenient to use observations made in harbour stations, where gravity was known from pendulum observations, for the determinations of the coefficients in the equation

$$\delta g = A_{\circ}\delta h + B_{\circ}\delta T + C_{\circ}\delta t.$$

From a knowledge of $A_{\circ}$, $B_{\circ}$, $C_{\circ}$ and the variations in h, T and t from their values at a primary standard station, the variation, δg, from the value at that station is theoretically obtainable for any observation made during the voyage.

The Results of the Test.

The generous provision by Messrs. Holt of a laboratory in the refrigerator of s.s. *Ascanius* has been referred to in previous reports and the excellent results as regards temperature regulation put on record. It was with the utmost disappointment that between Cape Town and Australia after nearly four weeks of continuous observation, it was discovered that all four barometers, instead of being sealed up, had developed leaks, and that they were responding to the changes in the external atmospheric pressure. This was in spite of great care on the part of the writer in assembling the apparatus, the whole reservoir having been coated, after screwing up, with white lead paint. It is believed that the leak occurred where a glass tube and tap runs into the cistern, and that a much better fit would be possible.

By collecting all the paraffin candles on board and melting them in a pot, into which the barometer tubes were immersed to about 8 inches, the writer, before reaching Fremantle, had sealed up all the barometers. But the opportunity of using the excellent refrigerator laboratory for the return voyage vanished on arrival in Adelaide, when it was found that war had broken out and that the ship had been commandeered as a troopship.

It has already been explained in the Interim Report that accommodation was found on R.M.S. *Morea* for the return voyage, but that the temperature regulation was exceedingly inefficient. Nevertheless, an attempt was made, and after resealing the barometers in Sydney Harbour, the whole of the foregoing operations were carried out on the *Morea* from September 9 to October 20, 1914.

It was not until the Armistice that the writer found an opportunity of attempting the immense labour of the measurement of the films and of the reduction of the results, but that occasion found him with a staff of officers of the Royal Air Force, some of them with considerable qualifications for the work. Other work being in abeyance, they readily agreed to

co-operate with him in this research. The films were measured up in the Physics Laboratory of University College, Reading, by Mr. Whittall, and the calculations carried out by Mr. F. S. Hayhoe and Mr. Harrenden Harker.

The first point to be decided was whether the variations in temperature during the course of each experiment, due probably in part at least to the lamps used for illuminating the mercury surfaces, occasioned a change which ruled the whole investigation out of account. It was, however, found that in general the mercury did not rise as the run proceeded, in spite of the usual increase in temperature registered on the stem. It was decided, therefore, to take the first reading of the stem thermometer as correct, and it was presumed that the lag of the barometer temperature was greater than that of the indicating thermometer on the stem within the casing.

The readings taken as standards were any four observations made at the following ports—there was usually a choice of two at each port :—Fremantle, Colombo, Bombay, Aden, Malta, Gibraltar.

The following are the constants in the above equation obtained by taking two Colombo and two Bombay observations as standards :—

$$A_o = -1{\cdot}2395, \quad B_o = 2{\cdot}0364, \quad C_o = 0{\cdot}131.$$

Whereas, taking one each for Colombo, Bombay, Aden and Malta, the values were

$$A_o = -1{\cdot}1364, \quad B_o = 1{\cdot}816, \quad C_o = 0{\cdot}211.$$

Using the former values, we note that Fremantle (Film 9) works out as $g = 978{\cdot}904$ instead of $979{\cdot}485$ given by pendulum observation, and that, if the data obtained from Fremantle (Film 8) are used, the value of g obtained is $978{\cdot}736$. There is thus no agreement between the values obtained from consecutive films for the same port. Similar discrepancies were obtained by using the second set of values, and other harbour stations provided equally unsatisfactory results.

The investigation was thereupon abandoned.

Discussion of the Method.

Apart from the possibility of leakage, which only was obvious in one barometer on the return voyage, there are difficulties in the method. One barometer could not be measured up because the image of the engraving could not be seen on the film, though visible during the adjustments. The great difficulty, however, lies in the temperature measurement. The value of the coefficient of δt ($C_o = {\cdot}211$) indicates that a variation in δt of $0{\cdot}1°$ C. means a change in the value of g of about ·02 cm./sec.^{2}; it is essential that this temperature should be measured on a thermometer graduated to divisions less than $1{\cdot}0°$ C. It is further necessary that this thermometer should read the temperature of the mercury within the barometer tube, and with the present arrangement this is not accomplished; it is important that the temperature lags of the barometer stem and of the attached thermometer should be equal.

The method of immersing the cistern in a vacuum flask, while satisfactory in preserving the temperature of the enclosed air at a nearly constant value during each run, involves a difference in temperature between various parts of the barometer tube, and this gradient cannot accurately be allowed for. On the homeward voyage, when temperature conditions were notoriously adverse, there was sometimes a difference between reservoir and stem which amounted to 3° or 4°. Even on s.s. *Ascanius*, where conditions were exceptionally favourable, there was seldom a difference less than 0°·2 to 0°·3. These considerations involve errors much larger than the differences in gravity which it is sought to discover.

The aneroid method with a plain mercury barometer is in this respect better than one which involves a gradient within the tube itself, though it has other objections.

It is the writer's opinion that all barometers used for gravity work must be of uniform temperature and that they should be immersed in a well-stirred bath of liquid which is kept at as constant a temperature as possible by a thermostatic device.

It is the writer's opinion that Hecker's method of an enclosed barometer, which is photographically recording, could, if modified in the respect indicated, be made to yield satisfactory results at sea.

In concluding this report upon the three methods tested during the voyages to and from Australia of the British Association in 1914, the writer expresses his thanks to Professor Hecker for giving him the opportunity of testing the apparatus and to the Council of the British Association for their grant from the Caird Fund for the purpose of these tests, which are only to be regarded as preliminary to what it is hoped may prove a successful attempt at a later date. For this purpose apparatus is already in course of preparation.

II. The Influence upon a Marine Barometer of the Ship's Motion through the Air. *By* Professor W. G. Duffield.

Before a further attempt is made to determine the value of gravity at sea there are certain problems to be solved. These are chiefly concerned with the behaviour on board ship of a mercury barometer, which in one form or another is employed in all methods to which extended trials have been given.

Both Hecker and the writer have had reason to question the accuracy of a comparison between readings made in harbour and those on the high seas, and a far more careful examination of the effect of the ship's vibration, due to the throbbing of the engines, as well as to the tossing on the waves, is necessary.

It was with the object of testing this point amongst others that the writer sought and obtained permission to carry out experiments on one of His Majesty's Destroyers, and in August 1919 two marine barometers were mounted on board *H.M.S. Plucky*, one in the chart-room below the bridge, where the vibration appeared to be least, and the other in the ward-room, where it was greatest. It was intended to compare their readings with one another and with those of a barometer on board a stationary

ship in the neighbourhood of which the Destroyer manœuvred. It was during these experiments that a new difficulty appeared which seems to add materially to the task of determining gravity over the ocean. It certainly adds to the difficulty of determining the effects of vibration.

The preliminary experiments showed that the vibration on a Destroyer in calm water does not greatly increase the difficulty of reading the instrument. Even when the ship was running at 22 knots in the sheltered waters off Spithead it was not difficult to obtain readings which were consistent to 0·1 mb., and the writer believes that on many occasions the readings were consistent to 0·05 mb., even with the ordinary vernier type of scale. Had the dial instrument previously employed by the writer been available, the readings could have been made with at least as great accuracy, and certainly much more quickly and easily.

August 29, 1919, was the first day of the trials, which took place off Spithead ; a fresh breeze was blowing from almost due west, which gradually strengthened to about 20 or 25 knots. It was found that the barometer in the chart-room suffered small fluctuations according to the direction in which the ship was heading ; this was at first attributed to the gravitational change due to the E.-W. motion of the ship, but, as the wind freshened, the fluctuations became much more marked, and of an order of magnitude which ruled this effect out of account as the main cause. Moreover, the ship's aneroid, also in the chart-house, showed similar fluctuations. It was evident that the changes of pressure were real, and that they were due to the eddy motion of the wind about the ship's hull. Going west the barometers in the chart-house showed invariably a reduced pressure, indicating a suction effect as the ship met the wind with a relative velocity of about 45 knots.

Typical readings in the chart-room are shown below, the aneroid referred to was that belonging to the ship :—

Time . .	11.19–11.26	11.30–11.39	11.43–11.53	1.16–1.26	1.30–1.42	1.46–1.55
Course . .	E	W	E	W	E	W
Mercury Bar.	994·4-994·7	994·0–993·6	994·0–994·4	993·2–993·9	993·2–993·8	993·5–992·6
Aneroid Bar.	987·8	987·0	987·2	986·0	986·8	985·5

The aneroid scale is very much in error, but the changes recorded by it are certainly real. Two features are obvious : (1) the fall going west against the wind, and the rise going east, the difference sometimes amounting to 1·3 mb., and (2) the gradual change in the reading of the mercury barometer during each run. The lag is due to the constriction in the barometer tube ; the lag of the aneroid was scarcely appreciable.

Closing the port-holes and the door of the chart-house made little difference to the readings, the fluctuations being just as marked as when they were all open. In the ward-room the barometer showed fluctuations in the same sense, a fall going west and a rise going east ; but the change was far less, amounting to 0·6 mb. as a maximum, of which 0·2 mb. is probably due to the gravitational effect of the E.-W. motion. Subsequent experiments with a specially sensitive aneroid confirmed the existence of these fluctuations, which are superposed upon any general atmospheric change of pressure. Few cabins could be more favourably situated for avoiding eddies than the ward-room, as its only opening to the deck is

through a lobby and up a companion-way barely wide enough to permit the entrance of a rotund seaman.

The point that the writer wishes to make is that, apart from the ordinary atmospheric changes of pressure which are troublesome enough, there are fluctuations which are due to the relation of the ship's motion to the speed and direction of the wind. An anemometer chart has only to be studied to show how variable these are, so that, even if the ship does not deviate from her course by a hair's breadth, there is ample reason for expecting changes during the time taken for an observation.

As far as the determination of gravity is concerned these fluctuations would not matter if both the mercury barometer and the comparison instrument, aneroid or hypsometer, possessed the same amount of 'lag,' but this is not the case, and there arises the possibility that the readings of the two instruments do not give truly simultaneous values of the pressure. To take an extreme instance—if the aneroid method of estimating gravity were employed, we should obtain a value for the acceleration due to gravity which at 1.55 P.M. would be 0·883 cm./sec.^{2} higher than the value calculated at 1.46 P.M. As we wish to measure gravity to ·005 cm./sec.^{2} we see that on an ocean liner moving through still air the fluctuations may introduce errors many times larger than this amount, unless special precautions are taken to obviate this source of error.

As the result of these experiments it appears that a new difficulty is added to the already complex problem of measuring gravity at sea. Such methods as employ a mercury barometer exposed to the atmosphere (as distinct from the enclosed type) are one degree less satisfactory than was hitherto supposed. In addition to a measurement of the atmospheric pressure by the height of a column of mercury, some other instrument for measuring it must be employed, and, if their lags are different, any additional fluctuation in the pressures to which the instruments are exposed adversely affects the accuracy of the method. In the method which the writer has already tested, whereby the readings of an aneroid are compared with those of a mercury barometer, the two instruments possess very different rates of lag, so that a momentary change of velocity in the wind will certainly affect one instrument more than the other; moreover, a comparatively small change in its direction may change the eddy pressure from a positive to a negative quantity. Probably the writer in his laboratory, in the refrigerator of the *Ascanius* or the *Morea*, protected by two very well-fitting doors from the rest of the ship, and situated in the bowels of the ship, was as free from this disturbing influence as one could possibly be on board; but, nevertheless, he was not quite secure against a possible fluctuation during the few seconds necessary for taking the aneroid readings.

Hecker's experiments were, as far as the writer can gather, carried out in passenger cabins which were presumably well above the water-line, and that is a disadvantage. He refers to one cabin as well ventilated, which might after all not be an advantage. In one voyage his work was done in two cabins, in one of which he had his barometer, and in the other his boiling-point apparatus. Without knowing how the cabins were ventilated it is impossible to say whether the results thus obtained

were reliable; if each had its own port-hole or its own cowl (as is arranged in 'inside' cabins) it is highly probable that there was a difference in the pressures in the cabins, and that the difference varied with the speed of the ship and the direction of the wind. Experiments should have been made to test their equality of pressure.

It is, however, easy in the light of later knowledge to find fault with Hecker's work, but after all it was the pioneer work in this branch of a very difficult subject, and it has guided the work of all experimenters who have followed.

It was rather surprising to watch a barometer falling at the rate of about 1 mb. a minute as the ship turned about; it might be useful to inform navigators of the effect of eddies in order that wrong meteorological inferences may not be drawn from barometric observations on fast-moving craft.

III. The Gravity Correction for the Ship's Motion in Longitude. *By* Professor W. G. Duffield.

Geophysicists who are interested in the determination of gravity at sea will remember that, on the completion of his voyages over the Atlantic, Indian and Pacific Oceans, Hecker published his conclusion that gravity at sea conformed within narrow limits to the formula obtained by Helmert from observations made at land stations. Eötvös, however, called his attention to a possible source of error which had not been taken into account. The ship when on an east or west course is subject to an increase or a diminution of the centrifugal force acting upon her, which results in an apparent decrease or increase in the value of gravity. During the course of subsequent experiments in the Black Sea, Hecker made two short series of observations to ascertain if this correction should, in fact, be made, and came to the conclusion that it should. Reference to Hecker's paper shows that he employed the boiling-point method, with which it is very difficult to get consistent results, and that he had reasons for rejecting the first set, which appeared to give positive results, and also that in the second set, upon which he relies, there appears, to the writer's judgment at least, to be a considerable degree of uncertainty. It was partly for these reasons, and largely for reasons which are discussed by the writer in his account of the influence of the motion of the ship through the air, that it was considered of importance to make a special examination of this point, in order that there should be no uncertainty in the matter; the effect of E.-W. motion is of such a magnitude that it might mask the variations of gravity that it is required to examine at sea.

Through the kindness of Captain Stapleton-Cotton, R.N., it was arranged that the destroyer *Plucky* should steam east and west alternately, while a comparison was made between the readings of the mercury and aneroid barometers which had been installed on board. The captain of the *Plucky*, Lieut. J. M. Smith, R.N., gave his whole-hearted co-operation, and to him and to the chief engineer is very largely due the successful issue of the experiments. In order that we might have a check upon the natural changes of pressure which occurred during the experiments,

Captain Backhouse, R.N., kindly arranged that observations of the barometer carried by the Battleship *Royal Sovereign*, which was anchored in the neighbourhood, should be taken simultaneously. The writer expresses his thanks to Lieut.-Commander W. R. Priston, R.N., for taking these readings at intervals of five minutes during the three hours required for the work.

The marine barometers were all of the Kew standard pattern, those on the *Plucky* being specially provided by the Meteorological Office for this work. The aneroid was that made by the Cambridge Scientific Company for the writer's previous experiments on gravity at sea,[1] but on this occasion a new mounting was devised. It was placed on a swinging table which was hung from a hook by rubber cords, a wooden rod supporting a heavy weight being screwed to the centre of the table to give it a longer period of swing; this acted very well, and obviated most of the small vibrations due to the engines. Chief Artificer-Engineer S. Dawson was chiefly responsible for its introduction.

On the first day of the trials it was evident that when the ship was on an east course the mercury barometer stood relatively higher than the barometer on the *Royal Sovereign*, and also than the aneroid reading, but that the difference only became marked when the *Plucky* had nearly completed her run of nine or ten minutes; this is, of course, due to the lag of the mercury barometer. The results were fully in accord with the existence of an effect due to E.-W. motion, but it was decided to repeat the observations with a longer run. Unfortunately the *Royal Sovereign* was not off Spithead during the second trial, but the stationary barometer readings on the first day gave the writer confidence in his interpretation of the readings on the moving ship. On the second day Captain Smith managed to find a longer stretch of sheltered water, which permitted a run of twelve to fifteen minutes in a true east or west direction at a speed of 22 knots, which gave better results.

On this day (September 1, 1919) the wind at the outset was from the south and estimated at about 3 knots. This direction was very favourable, because the speeds through the air were the same whether going east or west, and the disturbing influence was reduced to a minimum. Later in the day, however, the wind blew from the S.W. at about 8 knots, subsequently freshening to, say, 10 knots, when the observations became less reliable. Meeting the breeze on a west course, and doing 22 knots, the destroyer pitched a little, causing the aneroid to 'pump' appreciably; this, as has been explained elsewhere (*loc. cit.*), introduces a systematic error into its readings, making them too low.

The results of the day's observations are shown in the diagrams (fig. 4), in which the times are indicated on the horizontal axis and the reduced readings of the barometers in millibars on the vertical axis. The mercury barometer readings were treated according to the method of the Meteorological Office, the aneroid constant being determined by comparison with the mercury instrument in harbour. It was found that one division = 0·214 mb., rather less than in 1914. Since the aneroid possesses no absolute scale, its graph occupies an arbitrary position on the diagrams

[1] B.A Report, Newcastle, 1916.

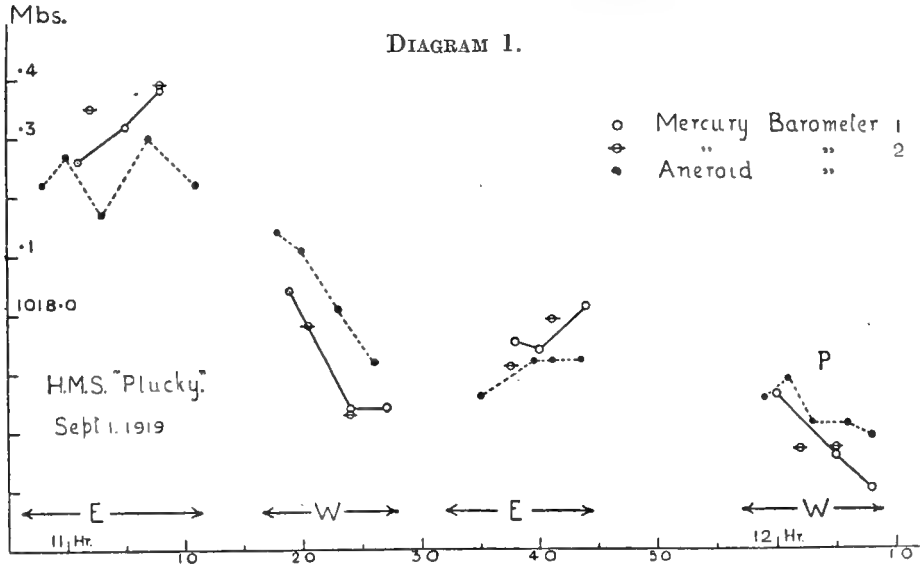


Diagram 1.

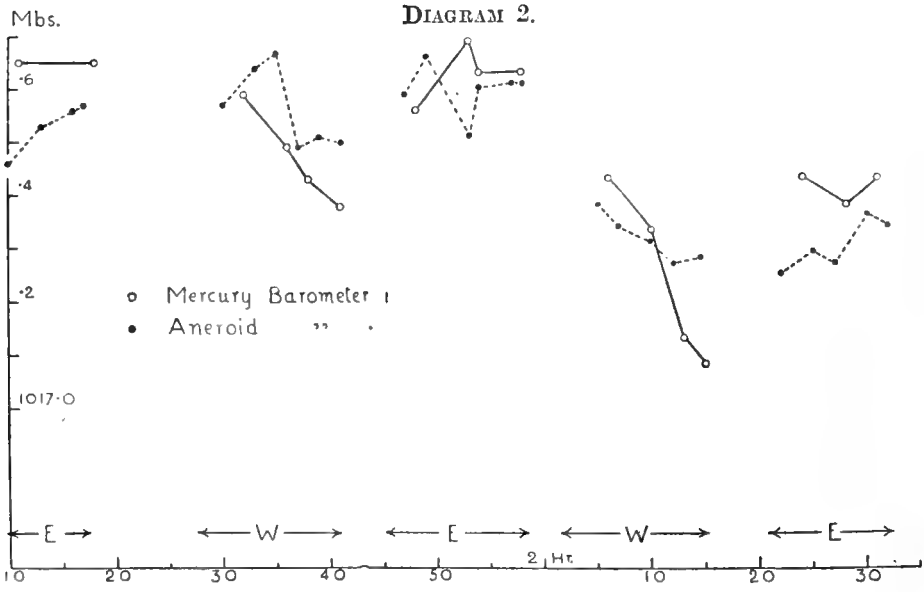


Diagram 2.

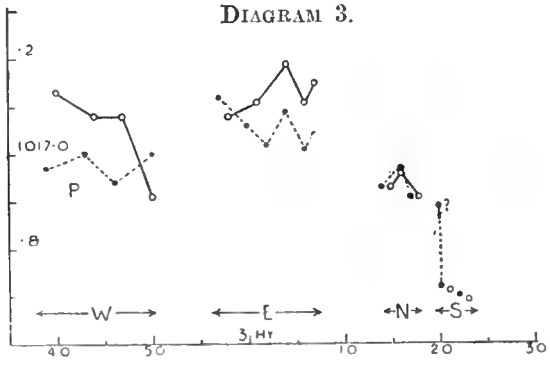


Diagram 3.

Fig. 4

It was, however, chosen so that it is approximately just as much below the mercury graph on the eastward run as it is above it on the westward run; the values of a vertical scale division are, of course, the same for the two barometers. As the aneroid was moved a few inches on its table at 12.10 P.M., the subsequent readings are not strictly comparable with those which preceded that time.

From the diagrams it indubitably appears that there is a rise of the mercury barometer when the Destroyer steams east and a fall when she steams west. The precise amount is difficult to estimate, but from the first three observations, made when the wind was on the beam and the sea smooth, the difference amounts to approximately 2 mbs. The subsequent readings, though made under less favourable conditions, in general agree with this. Where the 'pumping' was particularly noticeable the diagrams are marked 'P,' and there it is that the aneroid is erroneously low, and it is only at the end of the run, where the water was smoother and the pumping less troublesome, and when enough time had elapsed to enable the mercury to fall nearly to its true level, that the aneroid reading exceeds the mercury reading.

As a depression was approaching from the west, the fall in pressure going west was greater than the rise going east. Fortunately the aneroid possesses a very small lag, so with it small and rapid changes can be detected which would escape a boiling-point method. Mr. F. T. Whipple and the writer had tested the lag by taking the instrument up and down in the lift at the Meteorological Office. Each aneroid reading is the result of five separate observations, each of which took from two to three seconds.

The last two runs were made on north and south courses, and here, save for one observation, the agreement is remarkably good, the difference between the two barometers being in fact smaller than the probable error of each measurement.

The term involving the correction for E.-W. motion is $2\,\omega v \cos\lambda \sin\alpha$, where ω is the earth's angular velocity, v the speed of the ship, λ the latitude, and α the deviation of the ship's course from true north or south. For $v = 22$ knots, $\lambda = 50°\ 46'$, and $\alpha = 90°$, the expected difference between east and west amounts to 2·15 mbs. From comparison with the experimental results we may conclude with assurance that it is essential that this term shall be introduced into all gravity determinations made on a moving ship.

In the Committee's Report for 1916 (Newcastle) the writer, basing his conclusion upon an erroneous estimate of Hecker's experiments, assumed the necessity for including this term, and briefly discussed its bearing upon meteorological phenomena. During the War the attention of gunners was drawn to its application to ballistics. It is clear that a shell fired east will weigh less than when fired west; assuming a horizontal velocity of 500 metres per second, a shell fired at an 8,000-yard range will carry east about 80 yards further than if fired west in these latitudes. At the Equator the difference amounts to 120 yards; it seems useful, therefore, to introduce a bearing correction into gunnery. The load which an airship can carry also depends upon its speed and course; flying east at 60 knots an airship of 60 tons can carry about 100 pounds (the weight

of a fair-sized bomb) more than when flying west. During the war it is evident that in this respect the western position possessed a natural, though perhaps small, advantage.

In addition to Lieut. Smith, R.N., of H.M.S. *Plucky*, and others named in the text, the writer's thanks are accorded to Captain H. P. Douglas, R.N., for helping in the organisation of these tests, and to Mr. P. E. Turner for assisting in the reduction of the results. Once again the very kind assistance, which Sir Napier Shaw and the Meteorological Office Staff are always ready to give, is gratefully acknowledged.

Solar Observatory in Australia.—Report of the Committee, consisting of Professor H. H. Turner (*Chairman*), Professor W. G. Duffield (*Secretary*), Rev. A. L. Cortie, Dr. W. J. S. Lockyer, Mr. F. MacClean, *and* Professor A. Schuster. *(Drawn up by the Secretary).*

It will be remembered from previous reports that the Commonwealth Government accepted the offer to provide a considerable portion of the equipment of the Solar Observatory, and promised to proceed after the War with the necessary buildings upon the site of the temporary observatory at Canberra. This observatory at present contains the Oddie telescopes, which were contributed to further the purposes of this Committee in 1909; the six-inch Grubb Equatorial, presented by the trustees of the estate of the late Lord Farnham, reached Melbourne soon after the outbreak of war and awaits erection.

It is not considered that the present is an opportune time to press for the erection of the observatory buildings and the provision of the necessary staff.

Fuel Economy—Second Report of the Committee, consisting of Professor W. A. Bone* (*Chairman*), Mr. H. James Yates* (*Vice-Chairman*), Mr. Robert Mond* (*Secretary*), Mr. A. H. Barker, Professor P. P. Bedson, Dr. W. S. Boulton, Mr. E. Bury, Professor W. E. Dalby, Mr. E. V. Evans,* Dr. W. Galloway, Sir Robert Hadfield, Bart.,* Dr. H. S. Hele-Shaw,* Mr. D. H. Helps, Dr. G. Hickling, Mr. D. V. Hollingworth, Mr. A. Hutchinson,* Principal G. Knox, Mr. Michael Longridge, Professor Henry Louis,* Mr. G. E. Morgans, Mr. W. H. Patchell,* Professor L. T. O'Shea, Mr. E. D. Simon, Mr. A. T. Smith, Dr. J. E. Stead, Mr. C. E. Stromeyer, Mr. G. Blake Walker, Sir Joseph Walton,* Professor W. W. Watts,* Mr. W. B. Woodhouse, *and* Mr. C. H. Wordingham,* *appointed for the Investigation of Fuel Economy, the Utilisation of Coal, and Smoke Prevention.*

Introduction.

Soon after the Committee had drawn up its First Report, which was presented at the last meeting of the Association at Newcastle-on-Tyne in 1916, certain important developments took place in regard to the subject of its inquiry which it seems desirable now briefly to recount.

In July 1916, largely as the result of the work of the Committee, the Government, having at length realised the importance of the problem of fuel economy, appointed what afterwards became the Coal Conservation Committee of the Ministry of Reconstruction, under the chairmanship of Lord Haldane. Altogether seven of the then members of this Committee were invited, in their individual capacities, to serve on the Government Committee. An advance copy of the First Report was placed at Lord Haldane's disposal for the information of his Committee, which ultimately issued its Report and concluded its labours in 1918.

One of the first acts of the Coal Conservation Committee was to memorialise the Advisory Council (afterwards the Department) of Scientific and Industrial Research as to the need of a Chemical Survey of British Coalfields, a proposal which, it may be pointed out, had originated with this Committee, and had already been strongly urged in its First Report.

Matters having thus progressed so far, and it being clear that nothing further could be done without considerable grants of money, steps were taken, with the concurrence of the Council of the Association, to ascertain the attitude and intentions of the Advisory Council for Scientific and Industrial Research towards fuel research, and in

* Denotes a Member of the Executive Committee.

what way, if any, the work of this Committee could be assisted and co-ordinated with that of other similar bodies concerned in the matter.

On 2nd November, 1916, an informal conference was held at the Board of Education between representatives of this Committee and of the Advisory Council, with a view to arriving at some mutually satisfactory arrangement whereby the work of the Committee would be taken over and continued under the ægis of the new Department of Scientific and Industrial Research. It was then represented, on behalf of the Advisory Council, that it was their intention to set up, in the near future, a new Standing Committee on Fuel to organise and carry out, with adequate financial provision, the various lines of research already recommended by this and Lord Haldane's Committee, and that they desired to take over and incorporate in some way with the proposed new organisation the more active members of this Committee. Unfortunately, however, the plan then proposed for so doing (which would have been entirely acceptable to this Committee) was eventually set aside by the Department, which, in February 1917, established its own Fuel Research Board on a different basis. As it soon became clear that the new Board did not desire any assistance from an outside Committee, no basis of co-operation could be arranged, although the Committee had intimated to the Director of Fuel Research its willingness to collaborate.

For a period of a year afterwards the Committee did not meet, and its work was suspended, although a nucleus of its members informally kept in touch with developments. In October 1918, however, in response to a widespread and growing feeling that there was need of an organised body of independent scientific opinion that could be brought to bear, in the public interest, upon any proposals for research of public policy with regard to fuel, the Committee resumed its labours, having been empowered by the Association to reorganise its work and personnel, to enter into communication, at its discretion, with Government Departments, the Federation of British Industries, and other bodies concerned with fuel economy, and to publish from time to time through the medium of the technical Press, or otherwise, any information or recommendations in the national interest, without prejudice to the presentation of its Report to the Association.

Reorganisation.

The reconstituted Committee comprised thirty instead of (as formerly) forty-five members, and the number of the Sub-Committees was reduced from five to three, each with its own Chairman and Vice-Chairman, as follows:—

——	Number of Members	Chairman	Vice-Chairman
A. Chemical and Statistical . . .	12	Prof. Henry Louis.	Prof. W. W. Watts.
B. Carbonisation and Metallurgical .	9	Sir Robert Hadfield.	Mr. A. Hutchinson.
C. Power . . .	10	Mr. C. H. Wordingham.	Mr. W. H. Patchell.

Each of the following Societies and Institutions was invited to nominate for co-option (if not already a member) a representative on the Committee, which they did, as follows:—

(1) Federation of British Industries . .	Mr. A. T. Smith.
(2) Association of British Chemical Manufacturers	Mr. Robert Mond.
(3) Society of Chemical Industry . . .	Mr. E. V. Evans.
(4) Institution of Mechanical Engineers. .	Mr. W. H. Patchell.
(5) Institution of Electrical Engineers . .	Mr. C. H. Wordingham.
(6) Institution of Mining Engineers . .	Mr. G. Blake Walker.
(7) Institution of Mining and Metallurgy .	Mr. G. E. Morgans.
(8) Iron and Steel Institute . . .	Sir Robert Hadfield.
(9) Coke Oven Managers' Association . .	Mr. D. V. Hollingworth.

In addition, Mr. D. H. Helps has continued to represent the Institution of Gas Engineers, and Mr. H. James Yates the Society of British Gas Industries.

Finally, an Executive Committee of twelve members was appointed, including *ex-officio* the Chairman, Vice-Chairman, and Secretary of the General Committee, the Chairman and Vice-Chairman of each Sub-Committee, and in addition, one other representative member from each Sub-Committee.

Since its reconstruction the General Committee has held four meetings, whilst the Executive has met seven times. In view, however, of the vastness and complexity of the manifold issues involved in the present coal situation, and the difficulty of formulating any definite conclusion as to the effects of the war until conditions have become stabilised once more, the Committee decided to postpone presenting any final Report until some future year. The present Report is, therefore, of an interim nature, concerning such items only as appear to warrant publication at this juncture.

Coal Outputs and Prices since 1913.

In its First Report the Committee drew attention to the vital importance of relatively cheap coal to the nation's industrial prosperity, and stated that, for some years before the war, the average price of coal at the pithead had been decidedly on the up-grade, a tendency which might be expected to continue at an accelerated rate. As the result of circumstances created by, or arising out of, the war, the average pithead price of coal has already almost trebled since the year 1913, and is likely to rise still higher, a matter of most serious concern to the whole nation.

How basic is the necessity of relatively cheap coal to the recovery of our pre-war prosperity will at once be apparent when it is realised how absolutely dependent are all our principal manufacturing industries upon imported raw materials. Our own natural resources do not enable us to provide ourselves, in quantity sufficient for the needs of a modern industrial community, with a great variety of raw materials; nor can we grow sufficient food for our present population. But our ships can bring abundance of raw materials from all parts of the world to our coal. Without the impelling power of relatively cheap coal, we should neither be able to attract the raw materials, nor yet to build or maintain the ships in which to convey them. Relatively cheap coal

is, in fact, a fundamental necessity to the maintenance, not only of our great iron, steel, engineering, shipbuilding, and textile industries, but of our shipping trade and sea power.

Thus in 1913, the chief raw materials which we produced in excess of our requirements were coal, clay, and salt. By far the most important of these was coal, of which we exported 97·5 million tons valued (f.o.b.) at 52 million pounds sterling. Half of the 10·5 million tons of iron smelted in our furnaces was from imported ores. We imported also the whole of the copper and cotton, 95 per cent. of the zinc, 90 per cent. of the lead, and about 80 per cent. of all the wool and timber used in British industrial establishments. In addition, we imported some 257 million pounds' worth of food, drink, and tobacco.

The great need of the moment is that the true facts of the situation shall be brought home to all sections of the community. The Committee, therefore, desires to draw attention to the following comparative data concerning the movement of coal prices in Great Britain and the United States during the war-period. The British figures are all derived from official, or other equally reliable sources, whilst those relating to America have been extracted from the Bulletins issued by the Bureau of Labour Statistics (U.S. Department of Labour), to which the Committee desires to acknowledge its indebtedness. In converting the American prices into their English equivalents a dollar has been taken as 50 pence.

Outputs of Coal and Average Pithead Prices in Great Britain.

Year	Total Output Million Tons	Annual Output per person employed Tons	Average Pithead Price Per Ton
			s. *d.*
1913	287·4	260	10 1
1914	265·6	238	10 0
1915	253·2	270	12 6
1916	256·3	260	15 7
1917	248·0	247	16 9
1918	227·7	232	(24 0)[1]

[1] Estimated.

Prices per ton paid by Consumers in Great Britain.

Year	In London for Best House Coal delivered	For Gas Coal by the South Metropolitan Gas Co.		For Durham Coking Coal at a Cleveland Iron-works[2]
		f.o.b. at N.E. Coast	Cost into Works	
	s. *d.*	*s.* *d.*	*s.* *d.*	*s.* *d.*
1914	29 0	11 2	14 6	13 0
1915	34 3	15 5	22 11	16 2
1916	37 0	16 5	26 4	22 3
1917	38 0	16 8	32 5	22 10
1918	44 0	20 11	34 4	24 5

[2] The corresponding pithead prices would be about 3*s.* 6½*d.* less than these. The average price (at the works) during the first six months of 1919 has been 26*s.* 6*d.* per ton.

The upward tendency of prices has continued since the close of 1918, and, according to a recent declaration made on behalf of the Government in the House of Commons, consumers will have to face an all-round increase on the foregoing prices of 6*s*. per ton during the coming winter.

The Committee views with concern the recent rapid decline of the annual outputs per worker employed in British mines. During the thirty years preceding the war the returns had shown a steady decline, as follows:—

Decade	Average Annual Output per Worker Tons
1883–92	320
1893–02	295
1903–12	280

That this downward tendency was peculiar to British mines is shown by the following comparative figures:—

Comparative Annual Outputs per Worker employed in the Mines in

Triennial Period	Great Britain	Germany	United States
	Tons	Tons	Tons
1905–7	289	248	589
1908–10	265	239	591
1911–13	254	263	651

During the war the British outputs have continued to fall at an alarming rate, until in 1918 they reached the low level of 232 tons per worker employed. In marked contrast to this, the American figures have continued to rise at an accelerated rate until in 1916 they reached 732, and in 1917 the phenomenal record of 768, tons per worker employed. The official figures for the total production of coal in American mines in respect of each year since 1913 are as follows:—

Outputs of Coal in the United States during the Period 1913-17 *inclusive.*

Year	Total Output	Output per Worker employed at the Mines
	Million Tons	
1913	508·9	681
1914	458·5	601
1915	474·6	647
1916	526·9	732
1917	581·7	768

It would thus appear that in the year 1917 the American output per worker employed was more than three times that realised in British mines.

The following figures may be given, as showing how the wholesale prices of typical classes of American fuels have moved during the war:—

Average Wholesale Prices of Coal and Coke per Long Ton in the United States for each Year since 1913.

—	Stove Anthracite at New York	Semi-bituminous Pocahontas, f.o.b. Norfolk, Va.	Bituminous Pittsburg, Run of Mine, f.o.b. Cincinnati	Connelsville Coke
	s. *d.*	*s.* *d.*	*s.* *d.*	*s.* *d.*
1914	21 1	12 6	10 3	8 5
1915	21 0	11 10	10 3	8 4
1916	22 9	15 6	12 6	15 2
1917	23 5	22 8	21 5	38 6
1918	27 1	18 8	18 1	28 0

From an examination of the monthly returns it appears that, with the exception of those of anthracite, American wholesale coal and coke prices rose sharply during the latter half of 1916, and reached a maximum about the middle of 1917. Thus Pocahontas reached a maximum of 29*s*. 2*d*. (f.o.b. Norfolk, Va.) in May-June 1917, and bituminous one of 28*s*. per ton (f.o.b. Cincinnati) at the same period. Connelsville coke, which is that used in the Pittsburgh blast furnaces, touched a maximum of 57*s*. 2*d*. per ton in 1917. After that period prices fell 'under control.' Thus Pocahontas fell to a minimum of 16*s*. 3*d*. in August-October 1917, since which time they have steadily risen until in April 1919 they were at 20*s*. 5*d*. per ton. Bituminous fell to 14*s*. in September-October 1917, but have since risen to 18*s*. 8*d*. per ton (f.o.b. Cincinnati) in April 1919. Connelsville coke kept at 28*s*. for a period of fifteen months from October 1917 to December 1918 (both inclusive), since which it has steadily declined, month by month, until in April 1919 it stood at 18*s*. 2*d*. per ton. In the same month the price of Durham coke at the ovens was 33*s*. per ton *plus* a subsidy (paid by the Government) of 5*s*. 7*d*. per ton. It thus appears that already American fuel prices have fallen to a level considerably below those ruling in this country, a circumstance which gives American manufacturers a great initial advantage over our own.

Research on the Chemistry of Coal.

Since the previous Report, Professor Bone has continued to direct the research work upon the Chemistry of Coal at the Imperial College of Science and Technology, London, which he originally undertook in 1916 at the instance of the Committee. In conjunction with Mr. R. J. Sarjant he has recently published, in the 'Proceedings of the Royal Society,' the results of a series of experiments upon the so-called solvent action of pyridine upon coal, to which Bedson first drew attention in the year 1899.[3] Since that time it has been investigated by a number of other chemists as a possible means of discriminating between the chief types of constituents of the coal substance. Wheeler and his co-workers have employed it extensively in their researches, claiming that if the

[3] Bedson, *Journ. Soc. Chem. Ind.* 1908, p. 147.

portion of the coal removed by pyridine be subsequently extracted with chloroform, a complete separation of the resinic from the cellulosic constituents may be effected.[4] On the other hand, the independent work of Harger[5], Wahl[6], Vignon[7], and others raised the question whether the action of pyridine, and other similar basic solvents, is really one of ordinary solution, and much of the evidence obtained by them suggested that it is chiefly a depolymerising one. Professor Bone's recent experiments support this latter view, and point to the conclusion that the action in question affects the coal substance as a whole, and is by no means confined to any one constituent of it. The action is retarded, in a degree which may vary considerably according to the character of the coal, by the presence either of water in the solvent or of oxygen in the atmosphere in which the extraction is carried out. In order to obtain comparable results with a series of different coals it is, therefore, necessary to operate with a carefully dried solvent, and in an atmosphere from which oxygen is excluded. Suitable means and apparatus have been devised for carrying out extractions under such precautions. It has also been shown that the action of pyridine at its boiling point (under atmospheric pressure) upon a particular coal approaches in time a practical limit which, however, may be considerably exceeded if the extraction is carried out at higher temperatures (e.g. in sealed tubes under pressure). Professor Bone and his coworkers have also devised a method for extracting in a pure condition the resinic constituents of coal, particulars of which will shortly be published.

In connection with the question of the organisation of systematic investigations upon the chemical characters of the principal British coal seams, this Committee desires to reiterate the opinion expressed in its First Report, namely 'that the resources, both of existing laboratories which have been established in this country for the special investigation of fuel problems, and of other laboratories where the technique of the subject has been developed, might be utilised more than they are in this connection, and that the time is ripe for the organisation of a scheme of systematic co-operative research aided by national funds in which all such laboratories may participate.'

The Committee regrets to say, however, that, notwithstanding the establishment of the Fuel Research Board, with large funds at its disposal, no attempt has apparently yet been made to organise any such comprehensive scheme as was recommended in 1916; and it wishes again to impress upon both the public and the Department of Scientific and Industrial Research the danger of sterilising fuel research by a policy of over-centralisation. On the contrary, it is of the opinion that what is most needed is a broadly-planned policy which will aim at stimulating and assisting experimental work on the chemistry of coal, fuel economy, and cognate subjects everywhere throughout the whole Kingdom.

[4] Clark & Wheeler, *Trans. Chem. Soc.* 1913, **103**, p. 1704.
[5] Harger, *Journ. Soc. Chem. Ind.* 1914, p. 384.
[6] Wahl, *Compt. Rend.* 1912, **154**, p. 1094.
[7] Vignon, *Compt. Rend.* 1914, **158**, p. 1421.

Fuel Consumptions in the Iron and Steel and other Industries.

During 1916 the Committee circulated a series of carefully drawn questions among selected representative iron and steel works in Cleveland, Lincolnshire, Sheffield, and the Midlands generally, with a view to collecting reliable data concerning the then fuel consumptions in blast furnaces, steelworks, and rolling mills. This information has since been analysed and embodied in a Report which, by arrangement with the Council of the Iron and Steel Institute, is to form the basis of a full day's discussion on the question of fuel economy at their forthcoming Autumn Meeting in London on 18th September next. It will subsequently be published *in extenso* in their Journal, and thus be made available to the industry at an early date. On the same occasion also, a valuable Memorandum, written for the Committee by Mr. H. James Yates, on 'Fuel Economy in Cupola Practice' will be presented and discussed. The Committee is thus actively co-operating with the Iron and Steel Institute in promoting fuel economy in iron and steel works.

The Committee has also been in touch with the Federation of British Industries with regard to the setting up of an organisation for promoting fuel economy in industrial establishments generally, and for helping manufacturers by expert guidance on matters connected with the use of coal. The question was referred to a special Committee of the Federation, who reported to its Executive that it is in the province of the Federation to initiate a scheme, which it hopes shortly to do.

Electric Power Supply.

The Committee has had under consideration the recent Reports of various Government Committees upon the question of the reorganisation of Public Electric Power Supplies in Great Britain, which is now engaging the attention of Parliament. Whilst recognising the need of such reorganisation, and generally approving (*a*) of the proposed division of the country into areas in which the authorities dealing with the generation and main distribution of electricity shall be co-ordinated, and (*b*) of standardising in each of such areas the frequency and voltage of the main transmission and distribution system, the Committee desires to reserve any expression of opinion as to the best means of carrying out the needed reform until the Electricity Commissioners have been appointed and their specific recommendations for the various areas have been published.

Future Standards of Public Gas Supplies.

The Committee has had under consideration the Report issued on 29th January, 1919 (Parliamentary Paper, Cmd. 108) by the Fuel Research Board in reply to the inquiry of the Board of Trade as to 'What is the most suitable composition and quality of gas and the minimum pressure at which it should be generally supplied, having regard to the desirability of economy in the use of coal, the adequate recovery of by-products, and the purposes for which gas is now used.'

Recognising that the said Report opened up important and far-reaching questions of public policy with regard to the manufacture and

distribution of town's gas, the Executive, after receiving separate Memoranda on the subject from Professor Bone and Mr. E. V. Evans, referred the whole matter for detailed consideration to a Sub-Committee consisting of Sir Robert Hadfield, Professor Bone, Dr. J. E. Stead, Messrs. A. H. Barker, E. Bury, E. V. Evans, D. H. Helps, D. V. Hollingworth, A. Hutchinson, R. Mond, W. H. Patchell, and H. James Yates.

This Sub-Committee having reported that it had arrived, by an eight to one majority, at the conclusions embodied in the following numbered paragraphs, they were formally adopted by the Committee as a whole, and ordered to be incorporated in the Report as the findings of the Committee on the subject.

(1) The chief recommendations made by the Fuel Research Board embody substantially the following propositions:—

(*a*) That the consumer shall in future be charged according to the thermal units in the gas actually received by him, just as a consumer of electricity is charged for the Board of Trade units which have passed through his meter.

(*b*) That, subject to a maximum limit of 12 per cent. of inert constituents, and of its undertaking to adjust consumers' lighting, heating, and cooking appliances so that the gas can be burnt in them with both safety and efficiency, the gas undertaking shall be at liberty to fix the calorific value of the gas it supplies to its customers, although in the common interests of producers and consumers it is suggested that burners shall be standardised for a limited number of calorific values of gas of which (it is suggested) four grades may be sufficient, namely, 400, 433, 466, and 500 B.Th.Us. per cubic foot.

(*c*) That every supply district above a certain magnitude ought to be provided with one or more gas examiners and, if necessary, a staff of inspectors, whose whole time should be devoted to looking after the interests of gas consumers, and that the smaller supply centres should be grouped into districts for such purposes.

(*d*) That, provided customers' appliances are properly adjusted to the grade of gas supplied, it may be tentatively accepted that the relative values of different grades of gas are strictly proportional to their calorific values. Thus, for example, 'the relative values to the consumer of gases of 500 and 400 B.Th.Us. could be taken as exactly in that ratio.'

(*e*) That there shall be more complete removal of sulphur and cyanogen compounds from the gas.

(*f*) That, under normal conditions of supply and equipment, there shall be a pressure of not less than two inches of water in the gas at the exit of the consumer's meter.

(2) With regard to these recommendations, the Committee generally agrees that, provided (*a*) that simple and effective means or apparatus could be devised, and put in general operation, for determining

the heat units actually received by each individual gas consumer throughout the Kingdom, and (*b*) that certain other conditions (hereinafter set forth) were assured, it would be more equitable to charge the consumer on a basis of 'heat units' than on one of 'cubic feet' supplied.

(3) The Committee also agrees generally with the Fuel Research Board's recommendations as to (*a*) the maximum limit of 12 per cent. of inert constituents, and (*b*) the minimum pressure of two inches of water in the gas at the exit of the consumer's meter.

(4) The Committee considers that it should be the aim of any national policy in regard to gas standards to ensure (*a*) to the consumer, and especially to the domestic consumer, a supply of gas suitable to his requirements at the lowest cost consistent with reasonable safety, and (*b*) to the community at large, as great a recovery of valuable by-products in the carbonising process as is consistent with the production of a reasonably safe and usable gas. It certainly ought not to exclude the possibility of (*a*) distributing through the public mains surplus coke-oven gas or (*b*) securing, to a safe and reasonable degree, the advantages in regard to reduced costs of production accruing from the modern practice of steaming the incandescent coke produced by carbonising coal in vertical retorts on the continuous system. It by no means necessarily follows, however, that a gas undertaking ought to convert all its coke into water gas, as some of them apparently would like to do. It might conceivably be better policy to require gas undertakings, or at least some of them, to produce and supply the community with (*a*) a straight coal gas obtained simply by carbonising the coal, and (*b*) a free-burning coke, or semi-coke, fit for consumption in domestic grates.

(5) From information supplied to the Committee it would appear that, with regard to the quality of the gas generally supplied to consumers in days immediately preceding the war, the following figures may be quoted for the average gross calorific values, per cubic foot at 60° Fahr. and 30 in. barometer, of the gas supplied during the year 1913 in six of the largest cities of Great Britain:—

620, 596, 593, 582, 580, and 540 B.Th.Us.

Whilst it may be freely admitted that calorific value, although always an important one, is by no means the only factor to be considered in selecting a gaseous fuel for any particular purpose, the Committee is of the opinion that the proposal of the Fuel Research Board that in future gas undertakings may be allowed to supply, at their sole discretion, gas of any calorific value between 400 and 500 B.Th.Us., ought to be very carefully scrutinised in all its bearings, especially as it involves a considerable dilution of the old 'coal gas' by 'water gas,' with consequent much higher carbonic oxide and lower methane contents. Indeed the Fuel Research Board holds that 'the natural diluent for coal gas is water gas, made either from coke in a separate producer, or in retorts by steaming the hot coke.'

(6) The composition of the gas obtainable by carbonising British gas coals at high temperatures either in modern vertical retorts or coke

ovens, without steaming the charge, usually varies between the following limits, approximately:—

	CO_2	CO	CnHm	CH_4	H_2	N_2	
	2 to 3,	5 to 10,	2 to 4,	25 to 35,	45 to 55,	5 to 10	per cent.
Approx. Mean	2·5	7·5	3·0	30·0	50·0	7·0	

The calorific value of a gas of the mean composition indicated would be about 560 gross and 495 net B.Th.Us. per cubic foot at 60° Fahr. and 30 in. barometer. The corresponding values for a 'debenzolised' coke-oven gas, containing only 25 per cent. of methane, would be about 485 gross and 425 net. And inasmuch as the thermal efficiency of such carbonisation processes is admittedly high,[8] there would appear to be no particular reason, on the ground merely of thermal efficiency, for seeking to supersede the 1913 practice. The plea for the change is presumably based on the desire, on the part of gas undertakings, to convert a substantial part (or possibly the whole) of the coke into water gas, and thus to increase the gas-make per ton of coal at a corresponding sacrifice of the coke-yield.

(7) Water gas may be generated from coke with a thermal efficiency of (up to) 70 per cent.; it contains on an average:—

CO_2	CO	H_2	CH_4	N_2	
4·5	43·0	48·0	0·5	4·0	per cent.

Its calorific values per cubic foot at 60° Fahr. and 30 in. barometer are approximately 300 B.Th.Us. gross, and 275 net, or rather more than half those of the 'straight' coal gas already referred to. Its calorific intensity, however, is distinctly higher, but its range of inflammability with air considerably wider, than that of coal gas. Its high carbonic oxide content makes it a poisonous gas, and, owing to its high hydrogen and low methane contents, its mixtures with air are very liable to back-fire. For these reasons it is not a desirable gas for domestic uses unless largely diluted; and any large admixture of it with coal gas in public supplies would undoubtedly add materially to the dangers of carbonic oxide poisoning and of gas explosions in houses.

(8) With regard to the question of the dangers of carbonic oxide poisoning with a gas containing a large proportion of water gas, it may be recalled that twenty years ago this was the subject of an official Inquiry by a Committee appointed by the Home Office, of which Dr. J. S. Haldane and the late Sir William Ramsay were members. They had laid before them detailed information as to the Uses of Water Gas in the United States and its effect upon Human Health. In their Report (C. 9164 of 1899) they stated:—

> 'The most direct, and in our opinion, the only effective method of preventing danger from water gas is to fix a limit which the carbonic oxide in a public and domestic gas supply

[8] It has recently been shewn that the two Metropolitan Gas Companies in the year 1913 actually sent out in the form of gas, coke, and tar, rather more than 70 per cent. of the potential energy of the coal carbonised, and that over-all efficiencies exceeding 82 per cent. have been attained in large-scale carbonising tests.

> shall not, in ordinary circumstances, exceed. It is difficult to assign a limit applicable to all circumstances. In some cases 12 per cent. of carbonic oxide in the gas supplied might be proper, in others 16, or perhaps 20. . . . We are of opinion that with the present conditions of gas supply 20 per cent. is the highest proportion of carbonic oxide that should be allowed, and that this percentage should be used only under special circumstances. . . . Our attention has been called by several witnesses to the very imperfect and unsatisfactory gas-fittings often used in the poorer class of houses in large towns, and the constant leakages which exist without any attempt to discover or rectify them. . .'

Clearly then, the 1899 Committee, having in mind the nature of carbonic oxide poisoning and the faulty character of gas pipes and fittings in the poorer class of houses, considered that the carbonic oxide content of a public gas supply should in no circumstances be allowed to exceed 20 per cent., and only exceptionally 16 per cent. This Committee considers that even to-day a maximum limit of 20 per cent. of carbonic oxide ought not to be exceeded. It may be pointed out that the Fuel Research Board's recommendations would allow of a gas company distributing a 40 per cent. coal gas *plus* 60 per cent. water gas mixture containing between 27.5 and 30.0 per cent. of carbonic oxide.

(9) The Committee is unable to agree with the Fuel Research Board's apparent endorsement of the proposition that the relative values of different grades of gases are strictly proportional to their calorific values. On the contrary, they are of the opinion that the chemical composition of the gas is not a matter of indifference to the consumer, and that the cumulative results of forty years of scientific research on the subject prove that the fundamental properties of the explosive mixtures formed by different combustible gases with air, arising from their own peculiar chemical characters and modes of combustion, do affect profoundly their uses for power and heating purposes.

(10) It appears to the Committee that, in particular, the Board's Report does not recognise sufficiently the importance of methane as a constituent of a public gas supply. Owing to the relatively narrow range of explosibility of its mixtures with air, and the low speeds at which flame is propagated through them, methane (in addition to the advantages of its high concentration of potential heat units) as a constituent has an important ' steadying ' influence upon coal gas, rendering it eminently usable for domestic purposes. Hitherto the public has been accustomed to using a gas containing 30 per cent. or more of methane, and it is important that such proportions shall not be unduly diminished. Accordingly the Committee would urge the adoption of 20 per cent. as a minimum methane content in a public gas supply intended for domestic consumption.

(11) If the Committee's proposals in the preceding paragraphs be adopted as safe and reasonable in the interests of domestic consumers,

the gas might be sold (as proposed by the Board) on a thermal basis, subject to the following provisos:—

(*a*) that its methane content shall not be less than 20 per cent., its carbonic oxide content not more than 20 per cent., and its content of 'inerts' not more than 12 per cent.;

(*b*) that its gross calorific value per cubic foot at 60° Fahr. and 30 in. barometer shall not fall below 450 B.Th.Us.

Within such limits a gas undertaking would be at liberty to supply for domestic use either (*a*) 'straight' coal gas, (*b*) 'debenzolised' coke-oven gas, or (*c*) a mixture of 100 parts of coal gas with (up to) 50 parts of blue water gas. Where, however, gas is supplied in bulk for industrial uses only, a relaxation in the above conditions might be permitted subject to agreement as regards cost between gas undertakings and the consumers.

(12) In conclusion, the Committee hopes that scientific men generally will strongly support the important recommendation made in paragraph 53 of the Board's Report in regard to sulphur purification. The Board rightly urges 'the more complete removal not only of the sulphur compounds but also of the cyanogen compounds.' The important investigations carried out, from 1906 onwards, at the South Metropolitan Gas Works by Dr. Charles Carpenter, in conjunction with Messrs. E. V. Evans and Doig Gibb, resulting as they did in a process whereby the sulphur content of the gas sent out from these works has been reduced from 40 to about 8 grains per 100 cubic feet, constitute so notable an advance in the technology of gas purification that the time has surely come for legislative action in the direction of making such sulphur removal generally compulsory for all large gas undertakings.

Mr. D. H. Helps, representing the Institution of Gas Engineers on the Committee, dissented from certain of the foregoing conclusions on the grounds that if in future the consumer is charged for gas according to the number of heat units supplied to him in it, it will not be necessary to impose upon gas undertakings the restrictions in regard to inert constituents which the Committee has recommended. He was also opposed to the suggested limitation in regard to the carbonic oxide content, as well as to any re-imposition of the obligation upon gas undertakings to remove sulphur impurities other than sulphuretted hydrogen from the gas; and in regard to the question of pressure he was of opinion that a minimum of 1½-inch water gauge would be found sufficient.

During the discussions which took place upon the question of gas standards, the attention of the Committee was called to what is known as the 'stripping of coal gas,' by which is meant the extraction of benzenoid hydrocarbons from it. This process has been instituted as a war measure in view of the necessity for providing sufficient raw material for the manufacture of high explosives.

It was pointed out to the Committee, however, that with gas selling at its present average price it would probably be of greater financial advantage to the gas undertaking to allow the benzenoid hydrocarbons

to remain in the gas if the sale of gas on the proposed new thermal basis is instituted. Though fully realising the present national shortage of motor spirit, the Committee felt that gas undertakings should be under no obligation to remove benzenoid hydrocarbons unless the selling price of motor spirit would justify their doing so on financial grounds.

The Committee recommends that it be reappointed to continue its investigations, with a grant of 25*l*.

Rhynie, Aberdeenshire.—Report of the Committee, consisting of Dr. J. Horne (*Chairman*), Dr. W. Mackie (*Secretary*), *and* Drs. J. S. Flett, W. T. Gordon, G. Hickling, R Kidston, B. N. Peach, *and* D. M. S. Watson, *appointed to excavate Critical Sections in the Old Red Sandstone of Rhynie, Aberdeenshire.*

The plant-bearing cherts discovered by Dr. Mackie in the Old Red Sandstone at Rhynie, Aberdeenshire, when examined under the microscope, showed fragments of Crustacea in certain sections. Some of the sections were submitted to Dr. W. T. Calman and Mr. D. I. Scourfield, who have furnished the following report. 'The animal remains are, for the most part, very fragmentary and confused, but they are in an excellent state of preservation, even the fine feathering on small setæ being, in some cases, easily recognisable. All the remains examined appear to be referable to the class Crustacea, and to have belonged to animals comparable in size to the Copepoda of the present day. The most complete portions hitherto found have been tails, consisting each of a number of segments and ending in a furca. Both lateral and dorsal views have been seen, and the general arrangement of the parts fairly well made out. Two distinct species appear to be represented, belonging either to a primitive group of the Copepoda or to very small Branchiopoda (? Anostraca). Fragments of appendages are numerous in nearly all the slides, but are extremely difficult to interpret. One slide, however, shows a series of about three pairs of biramous feet in their natural connections. They are remarkably similar to the swimming feet of Copepods of the genus Cyclops, except that the branches are unjointed instead of being composed of the usual three segments. A considerable number of detached mandibles have also been seen, all of them most closely comparable to those of the Branchiopoda. It is evident that these remains are of extraordinary interest, and, although little progress has been made towards reconstructing any one of the several species that are represented in the material, enough has been done to show that, given a sufficient number of sections, the structure of the body and limbs could almost certainly be worked out, even if no entire specimens should be brought to light.'

During 1918 Mr. D. Tait, H.M. Geological Survey, obtained addi-

tional specimens of chert from the Rhynie outcrop, to be examined by Dr. Calman and Mr. Scourfield. A grant from the Royal Society has been received to aid the investigation.

Photographs of Geological Interest.—Nineteenth Report of the Committee, consisting of Professors E. J. Garwood (*Chairman*) *and* S. H. Reynolds (*Secretary*), Mr. G. Bingley, Dr. T. G. Bonney, Messrs. C. V. Crook *and* W. Gray, Dr. R. Kidston, Mr. A. S. Reid, Sir J. J. H. Teall, Professor W. W. Watts, Mr. R. Welch, *and* Mr. W. Whitaker. (*Drawn up by the Secretary.*)

Since the issue of the previous Report (Newcastle 1916) 205 photographs have been added to the collection, which now numbers 5,861.

Although the Committee has lost no member since the issue of its last Report, it has suffered an incalculable loss in the resignation of the Secretaryship by Professor Watts, who had held it since 1896. No one who has knowledge of the facts can doubt that the whole success of the Geological Photographs Committee has been due to his energy and business-like qualities. Fortunately Professor Watts is always ready to help and advise his successor.

For the first time for many years the Committee is not in receipt of any photographs from its most generous contributor, Mr. Godfrey Bingley. Mr. Bingley's name figures in the first list of contributors (Leeds 1890) and in two only of the subsequent Reports does he not appear. The number of photographs presented by him is as many as 1,123. The Committee wish to condole with Mr. Bingley most sincerely as regards the eye trouble which has interfered with his work, and trust that it may pass away.

Dorset is the county most fully represented in the present Report, sets having been contributed by the Secretary and by Mr. C. J. Watson. Mr. Watson, whose first photographs were received as early as 1892, sends a varied series, including examples from Cornwall, Derbyshire, Durham, the Isle of Wight, Monmouth, Nottingham, Stafford, Warwick, Worcester, Anglesey, Edinburgh, Antrim, and Kerry. The Secretary further contributes views from Cornwall, Cumberland, Gloucestershire, Lancashire, and Somerset.

Another early contributor, Mr. Henry Preston, sends photographs from Dartmoor and Nottingham, and a considerable series from Lincoln. Mr. J. W. Tutcher's work is illustrated by a set from Somersetshire illustrating a paper by Mr. L. Richardson, and contributed by him.

The Committee are very glad to welcome a new contributor in Dr. B. Pope Bartlett, who sends some photographs illustrative of the Cretaceous succession in the Mere and Shaftesbury districts, which are a model of what detailed stratigraphical photographs should be. Some characteristic views of the Burren, co. Clare, have been received from Capt. J. A. Douglas, having been taken by him and by Mr. E. R. Lloyd.

Photographs of considerable value have been received through Mr. Whitaker from the executors of the late Mr. H. B. Woodward. They include photographs of Cotham Marble, and of a perhaps analogous rock from the Purbeck, the latter being from negatives by Professor Watts. They further include views from Norfolk, Herts (Sir J. J. H. Teall), and Kent (H. C. McNeill), and three from Skye by Messrs. G. P. Abraham, Valentine and Sons, Ltd., and G. W. Wilson. The Committee are much indebted to Dr. Alfred Harker for the full descriptions, with illustrative sketches, which he kindly provided for the Skye views.

Mr. W. Whitaker sends a set of picture postcards, illustrating the geology of the neighbourhood of Brighton. Many excellent postcards of geological subjects are obtainable, and it is to be hoped that other contributors will follow Mr. Whitaker's example.

Photographs by Mr. J. G. Hamling, Miss E. Hendriks, Miss M. S. Johnston, Mr. J. H. Pledge, Miss H. D. Sharpe, Sir A. Strahan, Mr. G. W. Young and Mr. W. P. Young have also been received. To all contributors the Committee tender sincere thanks.

The Committee hope that before the issue of the next Report the new series of geological photographs which has so long been promised will be published. Reissue of the former series is also under consideration.

The Committee recommend that they be reappointed.

NINETEENTH LIST OF GEOLOGICAL PHOTOGRAPHS.

From September 1, 1916, to August 31, 1919.

List of the geological photographs received and registered by the Secretary of the Committee since the publication of the last Report.

Contributors are asked to affix the registered numbers, as given below, to their negatives, for convenience of future reference. Their own numbers are added in order to enable them to do so. Copies of photographs desired can, in most instances, be obtained from the photographer direct. The cost at which copies may be obtained depends on the size of the print and on local circumstances, over which the Committee have no control.

The Committee do not assume the copyright of any photograph included in this list. Inquiries respecting photographs, and applications for permission to reproduce them, should be addressed to the photographers direct.

Copies of photographs should be sent, unmounted, to

Professor S. H. Reynolds,
The University, Bristol,

accompanied by descriptions written on a form prepared for the purpose, copies of which may be obtained from him.

The size of the photographs is indicated as follows :—

L=Lantern size.	1/1 =Whole plate.
1/4=Quarter-plate.	10/8 =10 inches by 8.
1/2=Half-plate.	12/10=12 inches by 10, &c.

E signifies Enlargement.

ACCESSIONS 1916–1919.

ENGLAND.

BUCKINGHAMSHIRE.—*Photographed by* J. H. PLEDGE, 115 *Richmond Road, Dalston, N.E.* 1/4.

Regd. No.			
5640	( )	Bugle Pit, nr. Aylesbury	Contemporaneous erosion in Purbecks, about 1900.

CORNWALL.—*Photographed by* Miss E. HENDRIKS, 405 *Hagley Road, Edgbaston, Birmingham.* 1/4.

5641	( )	Gunwalloe, nr. Helston	Manaccan Beds (Devonian). 1913.
5642	( )	,, ,,	Contorted Manaccan Beds. 1913.
5643	( )	,, ,,	,, ,, ,, ,,
5644	( )	,, ,,	,, ,, ,, ,,

Photographed by Professor S. H. REYNOLDS, *M.A., Sc.D., The University, Bristol.* 1/4.

5645	(14·15) Delabole	Slate Works. 1914.
5646	(14·14) ,,	,, ,, ,,
5647	(14·35) Cataclews, Trevose	Sills of Minverite in Slate. 1914.
5648	(14·34) Dinas Head, Trevose	Spherulitic Adinole. 1914.
5649	(14·22) Church Hill Quarry, Port Isaac.	Pillow Lava. 1914.
5650	(14·21) Church Hill Quarry, Port Isaac.	,, ,, ,,
5651	(14·24) Pentire Head	,, ,, ,,
5652	(14·23) ,, ,,	,, ,, ,,
5653	(14·25) ,, ,,	,, ,, ,,
5654	(14·5) Brown Willy from Rough Tor.	Granite country. 1914.
5655	(14·8) Rough Tor	Weathering of Granite. 1914.
5656	(14·6) ,, ,,	,, ,, ,, ,,
5657	(14·9) ,, ,,	,, ,, ,, ,,
5658	(14·10) ,, ,,	,, ,, ,, ,,
5659	(14·11) ,, ,,	,, ,, ,, ,,
5660	(14·12) ,, ,,	,, ,, ,, ,,
5661	(14·13) ,, ,,	,, ,, ,, ,,
5662	(14·40) Lantern Pit, St. Austell	Schorl Veins in China Clay. 1914.
5663	(14·38) ,, ,, ,, ,,	China-clay Working. 1914.
5664	(14·39) ,, ,, ,, ,,	Big Schorl-rock Vein. 1914.
5665	(14·42) ,, ,, ,, ,,	Settling Tanks. 1914.
5666	(14·41) ,, ,, ,, ,,	,, ,, ,,
5667	(14·43) Roche Rock	Mass of Schorl-rock. 1914.

Photographed by C. J. WATSON, 14 *Bottville Road, Acock's Green, Birmingham.* 1/4.

5668	(2174) Trewavas	The Bishop rock, Weathered Granite. 1910.

CUMBERLAND.—*Photographed by* Professor S. H. REYNOLDS, *M.A., Sc.D., The University, Bristol.* 1/4.

5669	(74·13) Napes Rocks, Great Gable	1913.
5670	(71·13) West of Styhead Tarn	Fine bedded Tuffs. 1913.
5671	(70·13) Styhead Tarn.	Silting up of Tarn. 1913.
5672	(69·13) South of Rossthwaite	Boulder Clay on Glaciated surface. 1913.

DERBYSHIRE.—*Photographed by* C. J. WATSON, 14 *Bottville Road, Acock's Green, Birmingham.* 1/4.

Regd. No.			
5673	(2194) Derwent Reservoir . .	Contorted Yoredale Grit.	1910.

DEVON.—*Photographed by* Miss M. S. JOHNSTON, *Hazlewood, Wimbledon, presented by the executors of the late* H. B. WOODWARD. 1/4.

5674	( ) Pinhay Bay, Lyme Regis .	Junction of White and Blue Lias.	1906.

Photographed by G. W. YOUNG, *F.G.S.*, 20 *Grange Road, Barnes, S.W.* 1/4.

5675	( ) Between Combpyne and Lyme Regis.	'Cloud burst' effect.	1903.

Photographed by , *presented by the executors of the late* H. B. WOODWARD. 1/2.

5676	( ) Petitor Bay, Torquay . .	Cliff of Permian breccia.	1900.

Photographed by HENRY PRESTON, *Waterworks, Grantham, presented by the executors of the late* H. B. WOODWARD. 1/4.

5677	( ) Hound Tor, Dartmoor .	Weathering of Granite.	

Photographed by J. G. HAMLING, *F.G.S., The Close, Barnstaple.* 1/2.

5678	( ) Highdown Quarry, Codden Hill.	Chert Beds in Culm.	

DORSET.—*Photographed by* Professor S. H. REYNOLDS, *M.A., Sc.D., The University, Bristol.* 1/4.

5679	(1·17) Broad Beach, Kimeridge Bay.	Limestone band in Kimeridge Clay.	1917.
5680	(5·17) Gad Cliff from W. . .	Portlandian Section.	1917.
5681	(3·17) ,, ,, ,, ,, . .	,, ,, ,,	
5682	(7·17) ,, ,, ,, ,, . .	,, ,, ,,	
5683	(10·17) Gad Cliff from Worberrow Tout.	Portland Stone and L. Purbeck.	1917.
5684	(9·17) Gad Cliff from Worberrow Tout.	,, ,, ,, ,, ,,	
5685	(12·17) Worberrow Bay, E. end .	Wealden Section.	1917.
5686	(5·18) Worberrow Bay . .	Cretaceous Section.	1918.
5687	(2·18) Arishmell Gap and Flower's Barrows.	Chalk Cliffs and sub-chalk section.	1918.
5688	(9·18) Mewp Bay . . .	Lignite in Wealden.	1918.
5689	(10·18) ,, ,, . . .	Unio Bed, Upper Purbeck.	1918.
5690	(4·18) ,, ,, . . .	Wealden Section.	1918.
5691	(7·18) Mewp Rocks from Bindon Hill.	Sea Stacks of Up. Portland and Low. Purbeck.	1918.
5692	(11·18) Mewp Rocks . . .	Sea Stacks of Portland Stone capped by Low. Purbeck.	1918.
5693	(18·17) ,, ,, . . .	Sea Stacks of Portland Stone capped by Low. Purbeck.	1917.
5694	(19·17) ,, ,, . . .	Lower Purbeck Section.	1917.
5695	(20·17) ,, ,, . . .	,, ,, ,,	,,
5696	(14·18) Largest Mewp Rock .	Broken Beds in Cypris Freestone.	1918.
5697	(8·18) Bacon Hole, Mewp Bay .	Section Middle and Upper Purbecks.	1918.

Regd. No.		
5698	(17(*a*)18) Bacon Hole, Mewp Bay, and Worberrow.	Purbeck Section. 1918.
5699	(17·18) Bacon Hole, Mewp Bay .	Middle and Lower Purbeck Section. 1918.
5700	(19·18) Smuggler's Cave, Bacon Hole, Mewp Bay.	Lower Purbeck Section. 1918.
5701	(23·18) Bacon Hole, Mewp Bay .	Cherty Freshwater Bed. 1918.
5702	(20·18) ,, ,, ,, ,, .	Fold in Cypris Freestone. 1918.
5703	(30·17) Fossil Forest, Lulworth .	General View. 1917.
5704	(32·17) ,, ,, ,, .	Tufaceous Deposit round tree stumps. 1917.
5705	(31·17) ,, ,, ,, .	Tufaceous Deposit round tree stumps. 1917.
5706	(22·17) ,, ,, ,, .	Tufaceous Deposit round tree stumps. 1917.
5707	(24·18) ,, ,, ,, .	Caps and associated beds. 1918.
5708	(28·17) ,, ,, ,, .	,, ,, ,, ,, 1917.
5709	(22·18) ,, ,, ,, .	Dirt Bed and Caps. 1918.
5710	(28·18) ,, ,, ,, .	,, ,, ,, overlying Soft Cap. 1918.
5711	(25·18) ,, ,, ,, .	,, ,, ,, ,, ,, ,, ,,
5712	(29·17) ,, ,, ,, .	,, ,, ,, ,, ,, ,, 1917.
5713	(24·17) ,, ,, ,, .	Broken Beds. 1917.
5714	(27·17) ,, ,, ,, .	,, ,, ,,
5715	(25·17) ,, ,, ,, .	Broken and associated beds. 1917.
5716	(26·18) Lulworth Cove . .	Wealden Section. 1918.
5717	(29·18) E. side Durdle Door promontory, Lulworth.	Wealden and Purbeck Section. 1918.
5718	(30·18) Man of War Cove, Lulworth.	Crushed Flints. 1918.
5719	(42·17) Man of War Cove, Lulworth.	The Man of War from Durdle Door. 1917.
5720	(44·17) Durdle Door, Lulworth and Bull Rock.	Western Termination of the Portland 'Screen.' 1917.
5721	(47·17) W. side of Durdle Door promontory, Lulworth.	Purbeck and Cretaceous Section. 1917.
5722	(48·17) Chalk Cliffs, W. of Durdle Door, Lulworth.	Thrust plane traversing Chalk. 1917.
5723	(49·17) W. of Durdle Door, Lulworth.	Sea Caves worn along Thrust plane. 1917.
5724	(46·17) Durdle Door, Lulworth .	Vertical Chert Beds of Upper Greensand and Chloritic Marl. 1917.
5725	(31·18) ,, ,, ,, .	*Exogyra conica* in Upper Greensand. 1918.
5726	(32·18) White Nothe . . .	Upper Greensand Section. 1918.
5727	(33·18) ,, ,, . . .	,, ,, ,, ,,
5728	(39·18) Undercliff below White Nothe.	Weathering out of Chert in Upper Greensand. 1918.
5729	(37·18) Undercliff below White Nothe.	Weathering out of Chert in Upper Greensand. 1918.
5730	(38·18) Undercliff below White Nothe.	Weathering out of Chert in Upper Greensand. 1918.
5731	(36·18) Shore below White Nothe	Top of Upper Greensand and base of Chalk. 1918.

Photographed by C. J. WATSON, 14 *Bottville Road, Acock's Green, Birmingham.* 1/2 *and* 1/4.

5732	(983) Lulworth Cove, E. side .	Purbeck Section. 1893.
5733	(985) ,, ,, W. side .	,, ,, ,,
5734	(986) Stair Cove, Lulworth .	Contorted Middle Purbecks. 1893.
5735	(988) ,, ,, ,, .	Breach in the 'Screen.' 1893.

Photographed by Sir A. STRAHAN, *Director, H.M. Geological Survey, 28 Jermyn Street, London, W., presented by the executors of the late* H. B. WOODWARD. 1/4.

Regd. No.		
5736	( ) Stair Cove, Lulworth . .	Contorted Middle Purbecks.
5737	( ) Winspit Quarry, Isle of Purbeck.	Lower Purbeck on Portland Stone.

Photographed by Professor W. W. WATTS, *F.R.S., Imperial College of Science, S. Kensington, S.W., presented by the executors of the late* H. B. WOODWARD. 1/4.

5738	( ) Durlston Head, Swanage .	Lower Purbeck Limestone with Cotham Marble structure.
5739	( ) Durlston Bay, Swanage .	Mammillated surface of Lower Purbeck Limestone. Prior to 1895.

Photographed by W. P. YOUNG, *presented by the executors of the late* H. B. WOODWARD. 1/4.

5740	( ) Black Ven, nr. Lyme Regis	Lower Lias capped by Selbornian. 1906.

Photographed by Dr. B. POPE BARTLETT, *Bourton, Dorset.* 1/2 *and* 1/4.

5741	( ) Melbury Hill, Shaftesbury .	Junction of Lower Chalk and Upper Greensand. 1915.
5742	( ) „ „ „ .	Junction of Lower Chalk and Upper Greensand. 1915.
5743	( ) Cann Common, Shaftesbury	Passage Beds between Cenomanian and Selbornian. 1915.

DURHAM.—*Photographed by* C. J. WATSON, 14 *Bottville Road, Acock's Green, Birmingham.* 1/2 *and* 1/4.

5744	(110) Marsden rock, Sunderland .	Marine erosion of Magnesian Limestone. 1889.
5745	(104) Marsden	Marine erosion of Magnesian Limestone. 1889.
5746	(2473) Sunderland . . .	Concretionary Magnesian Limestone. 1912.
5747	(2474) „ . . .	Concretionary Magnesian Limestone. 1912.

GLOUCESTER.—*Photographed by* Professor S. H. REYNOLDS, *M.A., Sc.D., The University, Bristol.* 1/2.

5748	(43·18) Southmead bathing-pool Quarry.	*Caninia*-oolite and overlying dolomite. 1918.
5749	(42·18) Southmead bathing-pool Quarry.	On left *Laminosa*-dolomite, on right *Caninia*-oolite and dolomite. 1918.
5750	(45·18) Southmead bathing-pool Quarry.	'Sub-oolite bed' (top of *Laminosa*-dolomite).

Photographed under the direction of W. H. WICKES ; *presented by the executors of the late* H. B. WOODWARD. 1/2.

5751	( ) Redland, Bristol . .	Double Cotham Marble. 1906.

Photographed by ———— ; presented by the executors of the late H. B. WOODWARD. 1/2.

5752	( ) Near Bristol . . .	Abnormal Cotham Marble.

HANTS. (I. OF WIGHT).—*Photographed by* C. J. WATSON, 14 *Bottville Road, Acock's Green, Birmingham.* 1/4.

Regd. No.			
5753	(2434)	The Needles . . .	Chalk Sea-stacks. 1911.
5754	(2435)	,, ,, . . .	,, ,, ,,
5755	(2439)	Freshwater . . .	Sea-worn arch in chalk. 1911.
5756	(2441)	,, . . .	Sea-cave in chalk. 1911.

HERTS.—*Photographed by* Sir J. J. H. TEALL, 174 *Rosendale Road, West Dulwich, S.E.* 21, *presented by the executors of the late* H. B. WOODWARD.

5757	( )	Reed, 2 miles S. of Royston	Disturbed chalk.
5758	( )	,, ,, ,, ,,	,, ,,

KENT.—*Photographed by* H. C. MCNEILL, *Juniwari Mine, Ramtek P.O., Nagpur, India.* 1/2. *Presented by the executors of the late* H. B. WOODWARD.

5759	( )	Chiselhurst. . . .	Thanet Sand, overlying Chalk with old working.
5760	( )	Crayford	Junction of Thanet Sands and Chalk.

LANCASHIRE.—*Photographed by* Professor S. H. REYNOLDS, *M.A., Sc.D., The University, Bristol.* 1/4.

5761	(1·16)	Hampsfell, Grange-over-Sands.	Grikes in Carboniferous Limestone. 1916.
5762	(2·16)	Hampsfell, Grange-over-Sands.	Grikes in Carboniferous Limestone. 1916.
5763	(4·16)	Hampsfell, Grange-over-Sands.	Grikes in Carboniferous Limestone. 1916.
5764	(5·16)	Hampsfell, Grange-over-Sands.	Grikes in Carboniferous Limestone. 1916.

LINCOLN.—*Photographed by* HENRY PRESTON, *The Waterworks, Grantham.* 1/2 *and* 1/4.

5765	(1031)	Handley's Pit, Lincoln .	Middle Lias. 1905.
5766	(1030)	Lincoln	Ironstone quarry in Northampton Sands. 1905.
5767	(1025)	Little Ponton, Grantham .	Plateau Gravel Pit. 1905.
5768	(57)	Great Ponton . . .	Lincolnshire Limestone. 1893.
5769	(1090)	Welsford . . .	Upper Estuarine Beds on Lincolnshire Limestone. 1905.
5770	(492)	Old railway, Little Bytham	Cornbrash. 1900.
5771	(502)	Midland Railway cutting, Little Bytham.	Great Oolite Limestone. 1900.
5772	(1369)	Leadenham . . .	Ironstone in Northampton Sands.
5773	(1367)	,, . . .	,, ,, ,,
5774	(1368)	,, . . .	Undulating Ironstone in Northampton Sands. 1900.
5775	(1382)	Drake Stones, Anwick .	Boulders probably of Spilsby Sandstone. 1912.
5776	(1381)	Anwick	Glaciated end of large Drake Stone. 1912.

MONMOUTH.—*Photographed by* C. J. WATSON, 14 *Bottville Road, Acock's Green, Birmingham.* 1/2.

Regd. No.		
5777	(1138) Lancaut bend of the Wye, near Chepstow.	Incised meander.
5778	(1136) Near Chepstow	Anticline in Carboniferous Limestone.

NORFOLK.—*Photographed by* H. PRESTON, *The Waterworks, Grantham, presented by the executors of the late* H. B. WOODWARD. 1/4.

5779	( ) Thorpe Pit, Norwich . .	Norwich Crag Series.

Photographed under the direction of the late H. B. WOODWARD, *and presented by his executors.* 1/2.

5780	( ) Near Norwich and N. of Lowestoft.	Flints with appearance of working.

NOTTS.—*Photographed by* H. PRESTON, *The Waterworks, Grantham.* 1/2.

5781	( ) Hemlock Stone, Bramcote .	Stack of current-bedded Bunter cemented by barytes.
5782	( ) ,, ,, ,, .	Stack of current-bedded Bunter cemented by barytes.

Photographed by C. J. WATSON, 14 *Bottville Road, Acock's Green, Birmingham.* 1/4

5783	(1065) Hemlock Stone, Bramcote	Stack of current-bedded Bunter cemented by barytes.

SOMERSET —*Photographed by* ? *presented by the executors of the late* H. B. WOODWARD. 1/2.

5784	( ) Chilcompton railway cutting	Lower Lias and Rhaetic folded into a syncline and faulted against Dolomitic Conglomerate.

Photographed by Professor S. H. REYNOLDS, *M.A., Sc.D., The University, Bristol.* 1/2.

5785	(70·18) Quarry 3, left bank of Avon, Clifton.	*Caninia*-dolomites and shales (C_2 resting on *Caninia*-oolites (C_1). 1918.

Photographed by J. W. TUTCHER, 57 *Berkeley Road, Bishopston, Bristol, presented by* L. RICHARDSON, *F.R.S.E.* 1/2.

5786	( ) Sunnyhill Quarry, Cole, nr. Bruton.	Inferior Oolite—Doulting Stone to *Discites*-beds. 1914.
5787	( ) Strutter's Hill, nr. Cole .	Inferior Oolite—*Astarte obliqua*-bed to *Dumortieriæ*-beds. 1914.
5788	( ) Mill Pitch, nr. Cole . .	Inferior Oolite—Garantiana-beds. 1914.
5789	( ) Limekiln Quarry, Hadspen, nr. Castle Carey.	Inferior Oolite—Garantiana-beds and Hadspen Stone.

STAFFORD.—*Photographed by* C. J. WATSON, 14 *Bottville Road, Acock's Green, Birmingham.* 1/4 and 1/2.

Regd. No.		
5790	(1182) Kinver	Inhabited houses in Bunter Sandstone. 1894.
5791	(1087) Holy Austin Rock, Kinver.	Inhabited houses in Bunter Sandstone. 1894.
5792	(596) Tipton	Open Coal Workings. 1891.
5793	(932) Cox's Rough Quarry, Rowley.	Columnar Dolerite. 1898.

SUSSEX.—*Photographed by* A. W. W., *presented by* W. WHITAKER. Postcard.

5794	( ) Black Rock, Brighton .	Recession of coast by fall of cliff-drift overlying Chalk.
5795	( ) Devil's Dyke, nr. Brighton .	Dry Valley in Chalk.
5796	( ) Poynings from the Devil's Dyke.	Chalk Escarpment of South Downs.

Photographed by H. PRESTON, *The Waterworks, Grantham.* 1/4.

5797	( ) South Downs, nr. Eastbourne	Mass of ferruginous sandstone.
5798	( ) Beachy Head . . .	Weathered surface of Melbourn Rock. 1898.

Photographed by Professor W. W. WATTS, *F.R.S., Imperial College of Science, S. Kensington; presented by the executors of the late* H. B. WOODWARD.

5799	( ) Near Battle . . .	'Cutlet Bed' from Purbeck, before 1895.

WARWICK.—*Photographed by* C. J. WATSON, 14 *Bottville Road, Acock's Green, Birmingham.* 1/4.

5800	(2522) Icknield St., Birmingham .	Boulder clay with Erratic. 1913.
5801	(2533) „ „ .	„ „ „ „ „
5802	(812) Wilmcote . . .	Lias shale and limestone. 1893.

WILTS.—*Photographed by* Dr. B. POPE BARTLETT, *Bourton, Dorset.* 1/2.

5803	( ) Dead Maid Quarry, Mere .	Junction of Cenomanian and Selbornian (general). 1915.
5804	( ) „ „ „ .	Junction of Cenomanian and Selbornian (detail). 1915.
5805	( ) Norton Ferris, Kilmington .	Junction of Cenomanian and Selbornian. 1915.

WORCESTER.—*Photographed by* C. J. WATSON, 14 *Bottville Road, Acock's Green, Birmingham.* 1/4.

5806	(295F) Cotteridge Park, Birmingham.	Erratics. 1911.

WALES.

ANGLESEY.—*Photographed by* C. J. WATSON, 14 *Bottville Road, Acock's Green, Birmingham.* 1/2.

5807	(730) South Stack, nr. Holyhead	Marine erosion of Precambrian Schists. 1892.
5808	(729) „ „	Contorted Precambrian Schists. 1892.

CARNARVON.—*Photographed by* Miss E. HENDRIKS, 405 *Hagley Road, Edgbaston, Birmingham.* 1/4.

Regd. No.		
5809	( ) Merllyn, Criccieth . .	'Boulders' of Boulder Clay.

Photographed by ? *presented by executors of the late* H. B. WOODWARD. 1/2.

5810	( ) Tremadoc	Dolerite Sill.

GLAMORGAN.—*Photographed by* ? *presented by the executors of the late* H. B. WOODWARD. 1/1.

5811	( ) Southerndown Cliffs, E. part	Lower Lias limestone and shale.
5812	( ) Southerndown Cliffs, nr. Bridgend.	Lower Lias (Sutton Stone) unconformable on Carboniferous Limestone.

MERIONETH.—*Photographed by* Miss H. D. SHARPE, *presented by the executors of the late* H. B. WOODWARD. 1/4.

5813	( ) Near Harlech . . .	Peat cutting.
5814	( ) Near Bala Junction . .	Meanders of River Dee.

Photographed by C. J. WATSON, 14 *Bottville Road, Acock's Green, Birmingham.* 1/4.

5815	(1159) Llanbedr . . .	Erratics on glaciated surface. 1894.
5816	(244F) Pant Einion, nr. Barmouth Junction	Boulder clay on Vertical Cambrians. 1915.
5817	(2459) Sylfaen, Barmouth . .	The 'Sword Stones.' 1912.
5818	(2446) ,, ,, . .	,, ,, ,, ,,
5819	(2667) Barmouth . . .	Glacial Grooves.
5820	(846) ,, . . .	Entrance to Manganese Mine in Cambrian. 1894.
5821	(1398) Llanaber . . .	Submerged forest. 1897.
5822	(2462) Barmouth . . .	Sand ripples. 1912.
5823	(781) Cader Idris, upper part .	Ordovician Igneous rocks, intrusive and contemporaneous. 1893.
5824	(782) Cader Idris and Llyn-y-Gader.	Arenig and Llandeilo volcanic rocks and intrusive sills. 1893.

SCOTLAND.

EDINBURGH.—*Photographed by* C. J. WATSON, 14 *Bottville Road, Acock's Green, Birmingham.* 1/2.

5825	(765) Salisbury Crags, Arthur's Seat.	Dolerite on Carboniferous Sandstone. 1892.
5826	(762) Salisbury Crags, Arthur's Seat.	Dolerite on Carboniferous Sandstone. 1892.
5827	(760) Sampson's ribs, Arthur's Seat.	Columnar dolerite. 1892.
5828	(761) Arthur's Seat, Edinburgh. .	Volcanic agglomerate. 1892.

INVERNESS.—*Photographed by* VALENTINE & SONS, LTD., *Dundee, presented by the executors of the late* H. B. WOODWARD. 1/1.

5829	( ) Ben-na-Cailleagh, Broadford, Skye.	Granite mountains, Lias in foreground.

Photographed by G. P. ABRAHAM, LTD., *Keswick, presented by the executors of the late* H. B. WOODWARD. 1/2.

Regd. No.		
5830	( ) Cuillin's from Bruach-na-Frithe, Skye.	Gabbro scenery.

Photographed by G. W. WILSON, *Aberdeen, presented by the executors of the late* H. B. WOODWARD, $8 \times 5\frac{1}{2}$.

5831	( ) Blaven range from Torran .	Gabbro mountains, Cambrian limestone in foreground.

IRELAND.

ANTRIM.—*Photographed by* C. J. WATSON, 14 *Bottville Road, Acock's Green, Birmingham.* 1/2 and 1/4.

5835	(643) Giant's Causeway . .	The 'Giant's loom,' columnar basalt. 1892.
5836	(642) ,, ,, . .	The 'fan,' columnar basalt. 1892.
5837	(645) Giant's Causeway; the 'Spanish organ and chimneys.'	Basalt columnar and non-columnar. 1892.
5838	(2269) Cave Hill, Belfast . .	Dolerite dyke penetrating chalk and basalt. 1911.
5839	(2253) Ballypalidy . . .	Basalt columnar and non-columnar. 1911.
5840	(2234) Larne 'mad man's window'	Natural arch in chalk.

CLARE.—*Photographed by* Capt. J. A. DOUGLAS, *M.A., F.G.S., University Museum, Oxford.* 1/4.

5841	( ) Glencolombkille . . .	Edge of Burren plateau; reprod. Q.J.G.S., LXV. (1909) p. 546.
5842	( ) Burren	Terrace in the limestone escarpment; reprod. Q.J.G.S. LXV. (1909) p. 546.

Photographed by E. R. LLOYD.

5843	( ) Ballyveghan . . .	Natural limestone amphitheatre; reprod. Q.J.G.S. LXV. (1909) p. 546.

KERRY.—*Photographed by* C. J. WATSON, 14 *Bottville Road, Acock's Green, Birmingham.* 1/2.

5844	(699) Glengariff . . .	Glaciated rock.

JERSEY.—*Photographed by* C. J. WATSON, 14 *Bottville Road, Acock's Green, Birmingham.* 1/4.

5845	(1429) St. Helier . . .	Dyke in granite.

For Report of the Committee on Stress Distribution in Engineering Materials, see page 465.

Zoological Bibliography and Publication.—Report of the Committee consisting of Professor E. B. POULTON (*Chairman*), Dr. F. A. BATHER (*Secretary*), Mr. E. HERON-ALLEN, Dr. W. EVANS HOYLE, *and* Dr. P. CHALMERS MITCHELL.

SINCE the last published report, the attention of a few societies has been drawn to their custom of issuing authors' reprints without the required bibliographic details.

So far as work germane to this Committee is concerned, the activities of its secretary have mainly consisted in service on two committees, appointed respectively by the Conjoint Board of Scientific Societies and by the Council of the Royal Society to report on the future of scientific bibliography.

In *Science* for July 5, 1918, there appeared a set of rules adopted by the Entomological Society of Washington to govern publication in its *Proceedings*. Some of these are essentially the same as those already issued as suggestions by the Committee. Others, which seem to us worthy of general adoption, are the following:—

Rule 1.—No description of a new genus, or subgenus, will be published unless there is cited as genotype a species which is established in accordance with the current practice of zoological nomenclature.

Rule 2.—In all cases a new genus, or subgenus, must be characterised, and, if it is based on an undescribed species, the two must be characterised separately.

Rule 3.—No description of a species subspecies, variety, or form will be published unless it is accompanied by a statement which includes the following information, where known: (1) the type-locality; (2) of what the type material consists—with statement of sex, full data on localities, dates, collectors, etc.; and (3) present location of type material.

Rule 5.—The ordinal (or class) position of the group treated in any paper must be clearly given in the title or in parentheses following the title.

Suggestion 3.—In discussion of type-material modern terms indicating its precise nature will be found useful. Examples of these terms are: type [or holotype], allotype, paratype, cotype [or syntype], lectotype, neotype, etc.

Suggestion 4.—In all cases in the serial treatment of genera or species, and where first used in general articles, the authority for the species, or genus, should be given; and the name of the authority should not be abbreviated.

Suggestion 6.—When a species discussed has been determined by some one other than the author, it is important that reference be made to the worker making the identification.

We would also add, as a Rule, That when a new genus, sub-genus, species, or variety is introduced, it should be accompanied by a distinct statement that it is new, *e.g.* by the addition of 'n.sp.,' etc. Also that a species, etc., should not be described as new when it has been introduced in a previous publication.

Your Committee asks for reappointment, with a grant of £10 to defray the expense of circulating these and its previous suggestions among editors of zoological and cognate publications.

Archæological Investigations in Malta.—Report of the Committee, consisting of Professor J. L. MYRES (*Chairman*), Dr. T. ASHBY (*Secretary*), Mr. H. BALFOUR, Dr. A. C HADDON, *and* Dr. R. R. MARETT.

THIS year's work has consisted of excavations at Ghar Dalam, commenced in the summer of 1918, and still in progress. The grant of 10*l.* was spent in the exploration of that part of the cave floor separating the Trench described in the Report of the British Association of 1916, and Trench No. II, described in the Report published in the Journal of the Royal Anthropological Institute of 1917.

The layers in this part did not, of course, differ much from those described in the above-mentioned reports. Potsherds occurred in equal quantity, and belonged to various epochs, some being of a very fine pattern, a few implements were also met with, and animal bones were, as usual, found in great profusion. The most important fact, however, in this part of the cave floor is the occurrence of some human remains at a lower level than that in which the Neanderthaloid molars were found in 1917. This particular grant was exhausted by September 4, but the work continued, and was carried on for the greater part of the year, with only an interruption of about three months, the average number of men employed being six.

This work consisted in the digging of three trenches, which will be fully described in a report when the work is complete, and this will probably be in about two months more.

Trench I extends from the outer wall of Trench No. II of 1917 to an old rubble wall towards the entrance. It is about 30 feet long, having an average width of 25 feet. In this trench potsherds were found in profusion and belonged to various epochs. Animal bones were also found in the greatest abundance, and evidence of man's work has been traced to a rather low level.

Trench II is still nearer to the entrance of the cavern, extending from the above-mentioned rubble wall to Trench No. I of 1917. In both length and width this trench is practically equal to Trench I. As a considerable difference has been observed in the layers at various parts, two columns of material, about four feet in diameter, have been left standing for future reference, which, together with that part of the cave floor which has been left dividing the present trenches, will preserve for the cave an interest even when it is totally explored. In Trench II potsherds were not so common as in Trench I, but animal remains were found in equal abundance. Amongst the important finds in this trench are several specimens and many fragments of a marine shell belonging to a species which is at present very rare in Maltese waters, not to say extinct.

Trench III is still being excavated. It is situated further inside of Trench I, and is about 18 or 20 feet in length, and lesser in width than Trenches I and II. Here are to be seen some groups of stalagmites of various sizes, one of them being nearly equal to that described in my report of 1916. A coating of stalagmitic formation has preserved in this trench many of the animal remains in their anatomical position.

The state of the bones varied considerably in the various parts of the area excavated, some being very well preserved, others, however, could not be subjected to the slightest handling. Some of the smaller bones, especially, have already been sent to the British Museum, where they await determination. In none of the three trenches has the bottom of the cavern been reached, but in No. I and No. II we have come to a conglomerate of bones, consisting chiefly of teeth, which is very hard to dig, but which it is hoped to work when the digging up of Trench III is complete.

Experimental Studies in the Physiology of Heredity.—Report of the Committee, consisting of Dr. F. F. Blackman (*Chairman*), Professors Bateson *and* Keeble, *and* Miss E. R. Saunders.

During the past year the investigation carried on by Miss Saunders on the inheritance of surface characters in *Matthiola* has yielded the further evidence which was needed in order to render clear the factorial relations underlying the results obtained. These results show that *Matthiola incana* type and its well-known glabrous variety are not the isolated forms which they appear to be, but represent the end turns of a series, the intermediate members of which are characterised by a *gradual increase* in degree of hairiness in the course of development, so that the range in one grade overlaps that of the next in the series, in strong contrast with the *constant, uniform* appearance exhibited by the type and the wholly glabrous form. The range limits and the genetic behaviour of the several grades have now been determined, the appearance in one at least of the lower grades when hair development is almost at vanishing point being such as to suggest that we have in this case reached limiting physiological conditions.

It is proposed to continue the work on *Matthiola* and also certain experiments already in progress on other genera. The expensiveness of this work has much increased, and from last year's grant of 15*l.* they were unable to provide skilled labour. The Committee hope that it may now be found possible to increase the grant to 40*l.*, which sum falls a long way below the cost of the work.

Australian Fossil Plants.—Final Report of the Committee consisting of Professor W. H. Lang (*Chairman*), Professor T. G. B. Osborn (*Secretary*), Professors T. W. Edgeworth David *and* A. C. Seward, *appointed to cut sections of Australian Fossil Plants, with especial reference to a specimen of Zygopteris from Simpson's Station, Barraba, New South Wales.*

The Committee reports that the whole of the block of Zygopteris stem from Barraba has been sectioned after securing accurate casts of the

specimen. All the slides have safely arrived in Australia, and are in Mrs. Osborn's hands. The work of description is proceeding, but final results cannot be published until her return to England, it is hoped in 1920, owing to lack of essential literature in Australia. There is no immediate prospect that a committee operating from Adelaide will be able to secure further petrified material; hence the Committee feel that, the terms of appointment being fulfilled, its work is finished.

Australian Cycadaceæ.—Final Report of the Committee, consisting of Professor A. A. Lawson (*Chairman*), Professor T. G. B. Osborn (*Secretary*), *and* Professor A. C. Seward, *appointed to collect and investigate material thereof.*

The Committee regretfully reports that all attempts to secure regular supplies of cycads by post from Queensland and Western Australia have proved unsuccessful. Under the circumstances, therefore, the Committee does not ask for reappointment, and returns the balance of the grant herewith. A small amount of material, notably germination stages of *Macrozamia Frazeri* and some stages in development of the female cone of *Bowenia spectabilis*, has been secured and handed to Mrs. Osborn for investigation.

Museums.—Interim Report of the Committee, consisting of Professor J. A. Green (*Chairman*), Mr. H. Bolton *and* Dr. J. A. Clubb (*Secretaries*), Dr. F. A. Bather, Messrs. C. A. Buckmaster *and* M. D. Hill, Dr. W. E. Hoyle, Professors E. J. Garwood *and* P. Newberry, Sir Henry Miers, Sir Richard Temple, Mr. H. Hamshaw Thomas, Professor F. E. Weiss, Dr. Jessie White, Rev. H. Browne, Drs. A. C. Haddon *and* H. S. Harrison, Mr. Herbert R. Rathbone, *and* Dr. W. M. Tattersall, *appointed to examine the Character, Work, and Maintenance of Museums.*

The Committee have to report that their work has been suspended for two years, owing to the absence of members upon active service at home and abroad. Owing to the likelihood of the educational work of museums being recognised under the Education Act of 1918, the Committee are revising the several reports they had previously considered and bringing them up to date. A comprehensive statement upon the whole question will be presented at the 1920 Meeting.

The Committee present a report upon the relation of Overseas Museums to Education drawn up by the Secretary (Mr. H. Bolton) and Dr. W. M. Tattersall.

The Committee seek reappointment, with a grant of 15*l.*

Report of Secretary *and* Dr. W. M. Tattersall *upon Overseas Museums.*

Introductory Note.

Mr. Bolton and Dr. Tattersall were requested by the Committee to take advantage of the British Association Meeting in Australia to visit museums in the States and Australia, and to draw up a report thereon for the Committee's use. The following is an abstract of their report:—

Australian Museums.

West Australian Museum and Art Gallery.

Lectures are given by request upon museum collections on stated days to schools and classes.

A few museum lectures are delivered annually.

Special student series of specimens, furnished with explanatory labels, are now being set up.

Adelaide Museum.

Public lectures occasionally, but no definite educational scheme.

Australian Museum, Sydney.

Students and pupils of public and private schools and colleges are admitted by arrangement on Monday afternoons, and facilities for study given.

Evening lectures.

Technological Museum, Sydney.

No lectures are given in connection with the museum, but the specimens in the museum are lent to illustrate lectures given in the local technical colleges and lessons upon Nature study in the public schools.

Queensland Museum, Brisbane.

(1) *Elementary.*—Certain members of the scientific staff—chosen for this purpose—deliver elementary lectures and give demonstrations, with specimens, to classes not exceeding thirty students. Special afternoons are also allotted to junior classes of all grades to visit the galleries for the purpose of definite work, and a guide is placed at their disposal whenever one is desired.

(2) *Secondary.*—The remarks made under 'Elementary' apply also to this section, except that the lectures are of a more advanced character, and more care is taken in the selection of specimens, which, if opportunity permits, are handed round to each individual student.

(3) *Higher Education.*—The work in this respect is similar to that of the Universities, except that the staff are unable to give students any large amount of personal attention—rare instances excepted.

(4) *Research.*—Every facility is given for research, both to visiting students and members of the museum staff. Some of the latter are able to carry on solid work of this kind for the greater part of the year.

American Museums.

Academy of Sciences, Chicago.

This museum is now specialising upon natural history work for schools:

(1) By the formation of a large series of group cases of examples of the Illinois fauna, each group being set up in life positions, backed by coloured reproductions of the actual Illinois scenery in which the specimens lived.

(2) The provision of an extensive series of lantern slides, which are lent to the schools for lectures.

(3) Special series of natural study courses at the museum to teachers and to children delegates from schools.

(4) Laboratory courses for children are arranged after school hours and on Saturday mornings.

(5) Aquaria and a reference library are maintained for children.

(6) School visits are encouraged, and teachers and children are provided with lists of questions to answer from their observations of the museum specimens.

(7) Public lectures and lectures in schools are delivered by members of the museum staff.

(8) Future plans include the provision of a children's museum and lecture theatre.

Lecturing is paid for at a rate of fifteen dollars per lecture, and is not necessarily a part of the duty of the staff. Qualified lecturers are sometimes engaged from outside the museum.

Field Museum, Chicago.

A gift of $250,000 has been received for the formation of a Circulation Series of Specimens to Chicago schools. These are estimated to reach a quarter of a million of scholars. The Circulation Series are arranged in compact cases, furnished with pockets, in which are placed detailed descriptions of the specimens. Natural history specimens are mounted amongst natural surroundings.

The plans of the new museum include provision for lecture theatres in each of its four great departments, and for an elaborate scheme of supply of material and information to schools.

Art Institute, Chicago.

The character of the collections and their display is much similar to that of the Victoria and Albert Museum, South Kensington.

A large art school is maintained in connection with the museum, and many students work in the museum.

Art classes also work under guidance of teachers in the museum.

A full series of lectures are available for schools and classes which desire them.

Several lecturers (ladies) are attached to the museum, and frequently several lectures are delivered in the museum on the same day.

Carnegie Museum, Pittsburgh.

(1) *Elementary Schools.*—Visits of classes of school children to the museum are arranged under competent guides from the museum staff. Specimens are removed from the cases for the better instruction of school children.

Loan collections are made to schools.

Lectures to school children, and prize essay contests are arranged.

(2) *Secondary Schools.*—Special demonstrations similar in kind to those given to elementary schools are arranged, but of a more intensive character and more adapted to the higher attainments of the pupils.

(3) *Higher Institutions of Learning.*—Advanced students from the University attend the museum to carry on special researches under the direction of the staff, many of whom are also professors in the University.

Special provision is made for the instruction of the blind.

United States National Museum, Washington.

Members of the museum staff are also professors in the University, and have established the closest connection between the museum and the student, who carries out much of his study in the museum.

The museum is one of the recognised institutions at which research work can be done for the degree of Ph.D. of the George Washington University.

Boston Museum of Fine Arts.

The educational work of this museum is as follows:—

(1) Special Sunday docent services—*i.e.*, two informal talks by specialists, who give their services free, on Sunday afternoons, during the winter.

(2) Members of the staff meet visitors on request on weekdays for guidance through the museum. No charge.

(3) Public lectures:

(*a*) Museum school courses.
(*b*) University Extension courses. } Fees for both.

(4) Loan collections of lantern slides, photographs, and duplicate textiles and prints.

(4A) Loan collections for instruction.

(5) School of art in connection with the museum.

(6) Issue of free tickets to teachers and students.

(7) Free conferences by specialists on particular objects or groups of objects in the museum.

(8) Docent service for school children.

Metropolitan Museum of Art, New York.

Members, visitors, and teachers desiring to see the collections under expert guidance may secure the services of a member of the staff detailed for the purpose.

The service is free to teachers and to scholars under their guidance.

Easels and modelling stands may be used.

Copyists may be asked to satisfy the authorities as to their ability.

Copying permitted on all days except Saturdays.

Museum instruction for pupils of public schools. Schools pay part cost of lecture or part cost of course.

'Sample' classes are given to teachers.

Lectures also given to selected classes of children.

The city maintains one paid lecturer.

Regular visits are paid from schools for instruction upon the history of art.

Children are sent to the museum to study and then write up compositions upon the objects studied.

The University and the museum are in close co-operation, especially on classical and historical sides.

The director hopes yet to see a Faculty of Arts in the museum, with special lectures upon special collections.

American Museum of Natural History, New York.

This museum has for many years done a remarkable work in education. Its activities are much summarised in the following:—

Lecture courses for teachers.

Teaching collections.

Circulating Nature study collections to 501 schools in 1913, which reached over $1\frac{1}{4}$ million of pupils.

597 study collections for circulation.

Lectures to pupils.

A special guide service.

Special class-rooms for students.

30,000 lantern slides.

A large loan series of lantern slides.

Provision for blind students.

Propose to establish ten 'Lecture Centres' of 18 lectures per year in various parts of New York.

Suggested branch teaching museums in a number of centrally located schools.

Columbian University and the American Museum of Natural History.

Professors of the University lecture and demonstrate to their students in the museum, the Professors occupying the dual position of Curator in the museum and Professor in the University.

Specimens are provided for the students to handle.

Pennsylvania Museum.

Lectures are given to teachers, also addresses to children in classes of 50 to 200.

In the latter case teachers attend, and can thus follow up the instruction given.

The city has been asked to provide instructors.

At present the burden is thrown upon the museum staff.

The following educational establishments send students:—

(1) Preparatory schools.
Carrying students up to Matriculation standard.

(2) Small colleges.
(3) Grammar, higher grade schools, and ladies' colleges.
(4) Post-graduate classes. These do good work in museum.

Curators rank as Professors in the University.

The museum is supported by 15,000 dollars from State.

There is an endowment of 150,000 dollars and a bequest of 200,000 dollars, which yield 5 per cent.

All researches are published by the museum.

Philadelphia Commercial Museum.

Lectures every day to scholars from the public schools.

Occasional lectures to high school students and to University classes.

University Professors bring classes to the museum, and demonstrate at the cases.

The museum has sent out 600 cabinets of group preparations, showing various cereals, foods, ores, minerals, &c. Each shows its mercantile use and value.

The museum answers all inquiries, and also obtains information for business men. This work has proved of the utmost value to the commerce of the city.

Memorial Hall Museum, Philadelphia.

Art and industrial art collections only.

The museum is in close connection with technical schools of city.

Classes are held regularly at the museum.

The museum is specially used to stimulate art and industrial development, and in giving suggestions and aid to students in design and construction.

It is maintained partly by the city and partly by student fees.

Museum of the Brooklyn Institute of Arts and Sciences.

Possesses two docents:
(1) A museum docent.
(2) An art docent, maintained by an Art League.

The two lectured to 114,000 pupils in 1913.

Teachers and pupils are most appreciative and enthusiastic.

Children's Museum, Bedford Park, seeks co-operation with the schools:
(1) By correlating its exhibits with school courses of study.
(2) By maintaining a free reference library.
(3) By conducting courses of free illustrated lectures for school children.
(4) By lending charts and natural history specimens for class-room use, and
(5) By giving much individual attention and instruction in the exhibition halls.

Public Museum of Milwaukee.

Lectures are given for four classes:

(1) General adult public.
(2) School teachers.
(3) Students of normal, vocational, and high schools.
(4) Grammar school children.

The Education Department consists of:

A curator, associate lecturers, professional photographer and lantern operator, and an expert slide colourist.

Special Sunday afternoon and evening lectures are given.

Museum lecturers give 'talks,' or series of 'talks,' at the schools, or give lectures, or conduct parties through the museum upon request.

A science club is maintained for high school students.

Arrangements are made whereby all public school children of certain grades come to the museum twice each year for half-day visits.

The lessons of the American museums may be briefly summarised:

(1) They have solved in the most admirable fashion the problem of reaching all classes of students.

(2) The educational work is carefully systematised and adapted to the recipients.

(3) The range of influence of the museum has been in most cases determined, and the nature of the educational requirements, and these are well catered for.

(4) The highest degree and research work are encouraged, and the University and museum work in complete harmony.

TRANSACTIONS OF THE SECTIONS.

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Section A.—Mathematical and Physical Science.

President of the Section: Professor A. Gray, M.A., LL.D., F.R.S., F.R.S.E.

TUESDAY, SEPTEMBER 9.

The President delivered the following Address:—

I have devoted some little time to the perusal of the Addresses of my predecessors in this Chair. These have a wide range. They include valuable philosophical discussions of the nature of scientific knowledge and expositions of scientific method, as well as highly instructive *résumés* and appreciations of the progress of mathematics and physics. But as this is the first meeting of the British Association since the conclusion of peace I have decided to disregard in the main these precedents, and to endeavour to point out, in the first place, some of the lessons which the war has, or ought to have, taught our country and those who direct its policy, and in particular ourselves, whose vocation it is to cultivate and to teach mathematical and physical science.

Before proceeding with this task I must refer to the loss which physical science and the British Association have suffered this year through the deaths of Professor Carey Foster and Lord Rayleigh. Both of these great physicists were regular in attendance at the meetings of the Association, and they will be greatly missed.

What Carey Foster was as a man of science, as a teacher, and as a friend of all students of physics, has been worthily set forth in the columns of *Nature*, with all the knowledge and affectionate reverence of one who was at once his pupil and his fellow-worker at University College. To that eloquent tribute I will not, though I knew Carey Foster well, venture to add a word.

I shall not attempt to appraise here the work of Lord Rayleigh. But I may say that for something like half a century his name has stood not only for things that are great in physical discovery, but for sanity of judgment, and clarity, elegance, and soundness of treatment of outstanding and difficult problems of mathematical physics. His researches, too, in experimental science have been fruitful in results of the utmost importance in chemistry as well as in physics. With him there was no shirking of the toil of monotonous and systematic observation from day to day, in the pursuit of the greatest attainable accuracy: take, for example, his work on electrical units. But his influence on applied mathematics has also been enormous, and places him for all time in the foremost rank of the great physical mathematicians, at the head of which stands Isaac Newton. One has only to read his Treatise on the Theory of Sound, and his papers on Optics and Wave Theory, to find some of the most striking examples in all scientific literature of the working of a mind not only of the first order of originality, but imbued with a feeling for symmetry of form and clearness of exposition.

Lord Rayleigh's genius was, it seems to me, essentially intuitive and practical. Though he was not given to any striving after the utmost rigidity of formal proof, which, as he himself remarked, might not be more but less demonstrative to the physicist than physical reasons, no man made fewer mistakes. He is gone, but he has left an inspiring example to his order and to his countrymen of a long life consecrated to the object for which the Royal

Society, of which he had been the honoured President, was founded, the furtherance of Natural Knowledge.

The part which physical science has played in the conduct of the war on our side has been an important one, but it has by no means been so decisive as it might and ought to have been. And here lie the lessons which I think we can draw from the terrible events which have taken place. Some few people, mostly hostile to or jealous of science, whose vision of facts and tendencies seems to me to be hopelessly obscured by prejudice, would try to impose on the advance of natural knowledge and the supposed increased influence of scientific ideas on the minds of men, or, perhaps more precisely, on the diminution of the study of the so-called humanities, the sole or the main responsibility for the outbreak of war. It seems to me that a good many people allow themselves to be misled by a name. The name *Humanity* is given in the Scottish Universities to the department of the Latin language and literature, and in a wider usage the study of Latin and Greek is referred to as that of *Litteræ Humaniores*. But I am not aware that there is any more humanity, in the common acceptation of the term, about these studies than there is in many others. And experience has shown that the assertion that these studies have a special refining influence, while the pursuit of science has a brutalising tendency, is based on ignorance and partiality. The truth is that the man who knows nothing of science, and he who has neglected the study of letters, are both imperfectly educated.

Well, the accusation I refer to may be dismissed without argument. This is certainly not the time nor the place for a discussion of the causes of the war, or of the ethics of the extraordinary methods introduced into warfare by our enemies. But one thing I will say in this connection. Even poison gas is innocent in itself, and it occurs as a product in perfectly indispensable and eminently useful chemical processes. The extraordinary potency of scientific knowledge for the good of civilised mankind is frequently conjoined with a potency for evil; but the responsibility for an inhuman use of it does not lie with the scientific investigator. The guilt lies at the door of the High Command, of the high and mighty persons, themselves in feeling and temper utterly unscientific, who approved and directed the employment of methods of attack which destroyed the wounded and helpless, and wrecked for ever the health of many of those who emerged alive from the inferno.

As regards the help which British science was able to render in the defence against the German attack and the operations which followed when the fortune of war changed so dramatically, and the enemy was driven back towards the chain of fastnesses from behind which he originally emerged, one or two obvious reflections must have occurred to everyone. In one form or another these have been referred to by various writers, but I may recall one or two of them, for as a people we are incorrigibly forgetful and appear to be almost incapable of profiting from experience, which, according to the Latin proverb, teaches even fools.

Nearly twenty years ago the urgent necessity for the reorganisation of our military machinery had been, in the view of civilians at least, who had to bear the cost of the war in South Africa, demonstrated *ad nauseam*, but nothing of real importance in the way of reforming the War Office seems to have been done. The shocks we had received were forgotten, and soon the nation returned to its insular complacency, the old party cries resounded in the market-place, the hacks of party politics again resumed their occupation of camouflage and hoodwinking, and of giving 'parliamentary answers,' and the country drifted on towards its fate.

All this time an enormously powerful war machine was being built up on the Continent, and its different parts tested so far as that could be done without actual warfare. The real object of these preparations was carefully veiled by an appearance of frankness and professions of good will, though it was revealed every now and then by the indiscretions of the German military caste. To these indications and to others the country, ostrich-like, covered its eyes.

Now, it is often alleged that men engrossed in the pursuit of science are unbusinesslike, but I think that, if there had been any truly scientific element in the *personnel* of the Government (there never is by any chance), attention

would have been directed at a much earlier period to our hopeless state of unpreparedness for the storm which was gradually gathering up against us on the other side of the German Ocean. In discussions of our unpreparedness the emphasis has been placed on our lack of arms and munitions. But important as these are, the entire absence of a scientific organisation to guide us in the exigencies of a defensive war with the most scientific and most military nation of Europe was even more serious.

It is this deficiency in our organisation, a deficiency the avoidance of which would have had no provocative effect whatever, which concerns us here very specially. It is, moreover, a deficiency which, in spite of the lessons they have received, has, I fear, not yet been brought home to our military chiefs. When war broke out nothing had been done to ensure the utilisation for special service in the multitude of scientific operations, which war as carried on by the German armies involved, of the great number of well-trained young scientific men available in the country. The one single idea of our mobilisers was to send men to the trenches to kill Germans, and for this simple duty all except certain munition workers and men in the public services were summoned to the Army. Some modifications were made afterwards, but I am speaking of the failure of prevision at the outset. The need of men for special service, the inevitable expansion of the Navy for patrol and other purposes and the like, were, if they were thought of at all, put aside, without regard to the difficulties which would inevitably arise if these matters were delayed. Even how the new soldiers were to be trained, almost without rifles or machine guns, to meet the Germans in the field nobody knew. And I for one believe that but for the vigour and energy of Lord Kitchener, and the almost too late expression of conviction of our danger, and consequent action, by one outstanding politician, all would have been lost. We worried through, but at a loss of life and treasure from which it will take us long to recover, and which I could wish seemed to weigh more heavily on the minds and consciences of politicians.

The Germans, I believe, had a complete record not only of all their men fitted only for the rank and file, but also of all who had been trained to observe and measure. For the use of even the very simplest apparatus of observation a certain expertness in reading graduated scales, and generally a certain amount of trained intelligence is required. For this the laboratories of Germany amply provided, and the provision had its place in the enemy's mobilisation. Our people apparently did not even know that such a need existed or might arise.

In a letter which I sent to the Council of the Royal Society at the end of 1915 I ventured to propose that the Royal Society might set on foot an organisation of some such character as the following :—First, a Central Committee should be established, in some degree representative of the different centres of scientific teaching and work in pure and applied science. Then this Committee should nominate representatives at each centre, at least one at each University or College, and one at the headquarters of each local society, such, for example, as the Institution of Engineers and Shipbuilders of Scotland, and the similar Society which represents the North-East of England, and has its offices at Newcastle-on-Tyne. This arrangement, it was hoped, would enable the Central Committee to obtain readily information as to what men were available, and would therefore do something to bring the schools of science, and all the great workshops and laboratories of applied science, into co-operation. Thus could be formed at once a list of men available for particular posts, for the task of solving the problems that were certain to arise from day to day, and for the special corps which it was soon, if dimly, perceived were a necessity. Some such linking up of London with the provinces is really indispensable. The districts of, for example, the Tyne and the Clyde are too much ignored in almost all Government action of a general kind.

My letter was printed and sent out to some prominent men, by whom its proposals were highly approved. A Conference on its subject was held in London, and two special Committees were appointed. I was a member of one of these, the principal duty of which was to provide scientific men for special service. It included representatives of the various great departments, actively engaged in the conduct of the war. For some reason or other, which I never learned, the Committee after a week or two ceased to be called, and I believe that little was done in comparison with what might have been

accomplished. It was certainly not because such a committee would not work. Everybody was most willing, with proper notice, to attend such meetings as were involved, and to take any amount of personal trouble; moreover, the scheme was such as to provide that there should always be a nucleus of members in London to consult and act in any emergency.

I may briefly refer to one or two examples of the chaos which prevailed and the attempts that were made to cope with it. Very soon after the formation of the first Kitchener Army the organisation of the different corps apparently became a source of anxiety to the War Office. It began to be seen that officers in sufficient numbers could not possibly be obtained by the usual channels, so the expedient (a poor one by itself) was hit upon of placing the nominations to commissions in one at least of the two great scientific corps of the Army—the Royal Engineers—in the hands of the presidents of certain technical Institutions which have their headquarters in London. These gentlemen, with the help of the official secretaries, no doubt did the best they could, but a very regrettable, though perfectly natural, amount of strong feeling was evoked among the young scientifically educated men in the provinces, who were keenly anxious to join this corps. The Engineers, I may hardly say, is no refuge for men who are in the least concerned about their personal safety, for the percentage of casualties among Engineers on active service was notably higher than in the regiments of the line. Over and over again young engineers came to me, and complained that under the arrangements made they had no chance of obtaining commissions, or of qualifying as cadets, and begged me to write to the authorities. Of course, young graduate engineers do not as a rule join Societies such as the Institution of Civil, Mechanical, or Electrical Engineers, until they have made their way to some little extent, and begun to earn a little money.

The procedure I have indicated had in time to be relaxed, but such a Central Committee as I suggested, with antennæ stretching out to the educational and technical centres of the country would, I am sure, have recruited the Engineers quickly with the best possible material for officers to be found in the country, to the satisfaction of all concerned. It may be said that full information regarding every man in the country was in the hands of the authorities. In a sense this was true; the information existed in millions of returns, and thousands of pigeon-holes, but no attempt was made, or could be made, by office staffs in London, enormous as these quickly became, to digest and utilise it.

A large number of engineers and physicists and many others of mechanical skill and aptitudes found congenial occupation in the Royal Naval Air Service and the Royal Flying Corps; but even there, where things could be better done, since a new force had to be brought into existence, arrangements were to a considerable extent haphazard and ill thought out. Excellent self-sacrificing service was rendered by many, who risked and gave their lives, and of what was done we may well be proud. But from a scientific point of view there is room for great improvement. The, as I think, hasty and ill-considered amalgamation of these two branches of the Air Service, in which naval traditions were sacrified to those of the War Office, which deserved no such deference, will certainly have to be undone in the near future, or very greatly transformed. To anyone who considers the possibilities and probabilities of warfare in the future, it appears clear that this country will have to depend more and more upon its Navy, and that an Air Service Corps will be the companion of every division of our Fleet, with landings on the warships. Thus a new and highly scientific service, which will have to be to a great extent naval, is certain to be brought into existence.

Well, then, to return for a moment to my proposal to the Royal Society, why should the organisation which I suggested in 1915 not be established now? I wish all success to the League of Nations, but we shall prove ourselves even greater fools than we have been in the past if we do not use all possible means to prepare ourselves against eventualities. One attempt by our enemies outside our own borders to hold us to ransom has failed. Can we be so sure that no other attempt will ever be made, or that no *casus belli* between ourselves and another great nation will ever arise? This, I notice, is beginning to be assumed even in the midst of the welter of confusion and unrest that exists, and, among others, by just the very people who used to teach that the possibility of war was a great illusion.

The formation of a record of scientific graduates for special service ought not to be difficult. The material already in great measure exists. Each University and College has its roll of graduates or diploma holders, and with slightly more detailed entries these rolls would give the record. Each graduate of a University is kept track of through the necessity for keeping the electoral roll up to date, and it ought to be possible to devise a means of maintaining touch with the diploma holder. If each University or College were a local centre of the Central Committee, the making of the roll of graduates would be achieved at the different local headquarters, and would be a valuable supplement to the O.T.C. work now undertaken so willingly and done so well. The Government machinery which manages the O.T.C. movement might control the keeping of the register which I have suggested.

I turn now to another side of scientific work during the war. It was my lot to serve for nearly three years on the Inventions Panel of the Ministry of Munitions, and as the result of that experience I venture to make some observations on the utilisation of scientific knowledge and genius in the production of inventions useful for the public service. We had an enormous multitude of inventions to consider, and the Panel was divided into Committees for this purpose. For each invention or proposal a file or dossier was prepared and most carefully kept. There were also present at the meetings of the Panel very efficient officers representing different branches of the service. Everything received careful attention, and for the ability and fairness with which the initial examination was made by the corps of examiners, and the *précis* of the invention presented, I have great admiration. Much has been said about the inefficiency and the mistakes of various Government Departments during the war. The Ministry of Munitions Inventions Department was, so far as I could see, eminently well managed.

Many of the so-called inventions were not inventions at all. Some were not at all new; in other cases an idea only was mooted. Could so-and-so not be done? and so on, and the Department was supposed to be grateful for the idea, and to do the rest, besides rewarding the proposer. A favourite notion, which illustrates the diffusion of scientific knowledge among different classes of people, was that of taking a magnet—any magnet—up on an aeroplane, and using it to attract Zeppelins and other aircraft. Others suggested electromagnets fed by machines which would have involved carrying into the air on an aeroplane a fully equipped power-house! Another favourite idea, inspired, no doubt, by a certain sensational type of article in the fiction magazines, was that of rays charged in some way with electricity, or some other mysterious agency, and *therefore* intensely destructive!

But there was a residuum of valuable inventions, which fully justified the existence of the Department. These were recommended for further consideration by the various departments of the services, or by General Headquarters. It by no means followed that all that came to this stage received careful further consideration. Everybody was very hard worked, and many were overdriven. And it was by no means certain that when important approved appliances were sent to G.H.Q. a thoroughly well-informed and capable officer would in all cases have the duty of explaining and showing their action. The absence of such an officer, I am sure, often resulted in delay and serious error, and, I fear, also in the rejection of what was in itself exceedingly good, but was not understood. People who knew nothing about the matter took charge, and ordered things to be done which brought disaster to the apparatus. I know of one very important machine which was ruined, with much resulting delay. A Brigadier- or Major-General, with a confidence born of blank ignorance, ordered a motor generator to be put on town electric mains, and of course burnt it out.

Then, again, we were told that G.H.Q. did not want this or that, and here, as in all human affairs, mental inertia certainly played a considerable part. The willingness, however, of some departments to adopt at once a device captured from the enemy was pathetic. Often quite clumsy and relatively inferior contrivances were adopted in the midst of hesitation about our own. Anything German of this sort some people assumed must be good—a foolish idea, the result of want of confidence, often well founded I am afraid, in their own

judgment. It is legitimate to copy from the enemy, and in several important things we have not been slow to do so.

The delays that occurred were to some of us at home, who were anxiously dealing with all kinds of contrivances, exceedingly exasperating. Some were undoubtedly unavoidable, but others were, as I have indicated, far otherwise. Deficiency in scientific education was the cause. It is to enforce the need for such education that I refer to such matters at all. The " playing fields of Eton " are all very well. I for one do not scoff at what the old saying stands for, but scientific laboratories and good intelligent work in them are indispensable. A man who directs in whole or in part a great machine must know something of its structure and capabilities. This apparently does not hold in politics.

I feel bound to allude to another aspect of the inventions business which to my mind was very serious. In doing so, however, I wish it to be clearly understood that I am criticising a system and in no way here referring to particular individuals concerned in its administration. Various inventions which had passed satisfactorily the first examinations by responsible judges were submitted to technical departments at home to be subjected to practical tests. These inventions were, frequently, solutions proposed of problems on which technical officers, of the departments required to conduct the tests, had long been engaged. It was natural, indeed inevitable, that some of these officers should have come to regard the solving of these problems as their own special job, and so did not much welcome the coming of the outside inventor. Then, no doubt, they often felt that they were just on the point of arriving at a solution—a feeling that certainly could not facilitate the avoidance of delay. It was manifestly most unfair to ask them to judge the work of the outside inventor, or to place in their hands details of his proposals, for exactly the same reason which in civil life restrains a man from acting as a juror in a case in which he is personally interested. Nobody of good sense feels offended when attention is called to such a rule in practice.

Thus I have no hesitation in expressing the opinion that a testing board of practical, well-qualified physicists and other experts, with a properly qualified staff, should be formed for the purpose of carrying out all tests of inventions. No insuperable difficulty would, I believe, be experienced in forming such a board. It should be formed carefully, not by more or less casual nomination of one another by a few persons. Expert knowledge of a subject should be a necessary qualification; the so-called 'open mind' of the much-lauded but untrained practical man is not worth having. But on that board neither inside nor outside inventors of the same kind of appliances should have any place, though of course consultation with the author of an invention under test would be absolutely necessary. Also those actually carrying out the tests and those collating the results should not be men in any way in the employment of or under the supervision of inventors, whether 'outside' or 'inside.' It is imperative in the interests of the country that delay in such matters should be avoided, and that all such work should be done without fear or favour.

The value of University and College men trained in science has been thoroughly proved in the Artillery, the Engineers, and in their offshoots, the Special Sound Ranging and Survey Corps, though its recognition by the authorities of Whitehall has been scanty and grudging. Some of the old-fashioned generals and staff officers could not be got to see the use of men who had not been trained to field exercises by a long course of drill. What is the good of officers, they said, who are not skilled leaders of men? This is the old crude idea again of destroying Germans with rifles, bayonets, and hand grenades. The falsity of these antiquated notions has now, I believe, been amply demonstrated.

The objection to these men, however, lies a good deal deeper. Even those scientifically educated officers who came into the new armies when they were formed, and were trained by the service of years of warfare superadded to the initial course of drill, have been demobilised in a nearly wholesale manner, without the least regard to even very exceptional qualifications. Many of these were, it seems to me, the very men who ought, above all, to have been retained in the service. Now (though, as I write, improved regulations are being

issued) they are to a great extent to be replaced by the Public School *cum* Sandhurst young gentlemen, who, it appears, are the 'pucca' officers *par excellence*.

The old system of the rule of politician chiefs whose only or main function is to sign the edicts of heads of departments seems to have returned in full force, and the coming of the cleansing Hercules that many people desire for the War Office does not seem to be within the bounds of possibility.

The real cause of the prevailing neglect of science, with all its pernicious results, is that almost all our political leaders have received the most favoured and fashionable form of public school education, and are without any scientific education. An education in classics and dialectics, the education of a lawyer, may be a good thing—for lawyers; though even that is doubtful. For the training of men who are to govern a State whose very existence depends on applications of science, and on the proper utilisation of available stores of energy, it is ludicrously unsuitable. We hear of the judicial frame of mind which lawyers bring to the discussion of matters of high policy, but in the majority of scientific cases it is the open mind of crass ignorance. The result is lamentable: I myself heard a very eminent counsel declare in a case of some importance, involving practical applications of science, that one of Newton's laws of motion was that 'friction is the cause of oscillations'! And the helplessness of some eminent counsel and judges in patent cases is a byword.

As things are, eminence in science is no qualification; it would even seem to be a positive disqualification, for any share in the conduct of the affairs of this great industrial country. The scientific sides of public questions are ignored; nay, in many cases our rulers are unconscious of their existence. Recently in a discussion on the Forestry Bill in the House of Lords a member of that illustrious body made the foolish assertion that forestry had nothing to do with science; all that was needed was to dig holes and stick young trees into them. Could fatuity go further? This hereditary legislator who, as things are, has it in his power to manage, or mismanage, the conversion into available energy of the radiation beneficently showered on a certain area (his area) of this country of ours does not seem to be aware that the growing of trees is a highly scientific industry, that there are habits and diseases of trees which have been profoundly studied, that, in short, the whole subject of silviculture bristles with scientific problems, the solutions of which have by patient labour been to a considerable extent obtained.

Take also the case of the Dyes Industries. The publicists and the 'good business men'—the supermen of the present age—who wish to control and foster an industry which owes its very existence to an English chemist refuse to have on the Committee which is to manage this important affair any man of scientific eminence, and no remonstrance has any effect. These great business men are as a rule not scientific at all. They are all very well for finance, in other respects their businesses are run by their works-managers, and, in general, they are not remarkable for paying handsomely their scientific assistants.

I myself once heard it suggested by an eminent statesman that an electrical efficiency of 98 per cent. might by the progress of electrical science be increased fourfold! This, I am afraid, is more or less typical of the highly educated classical man's appreciation of the law of conservation of energy; and he is, save the mark, to be our minister or proconsul, and the conservator of our national resources. It is not surprising, therefore, that in connection with a subject which for several weeks occupied a great space in the newspapers, and is now agitating a large section of the community, the nationalisation of our coal mines, there was not a single word, except perhaps a casual vague reference in the Report of the Chairman, to the question, which is intimately bound up with any solution of the problem which statesmen may adopt, I mean the question of the economic utilisation, in the interests of the country at large, of this great inheritance which Nature has bestowed upon us. In short, are Tom, Dick, and Harry, if we may so refer to noble and other coalowners, and to our masters the miners, to remain free to waste or to conserve at their own sweet will, or to exploit as they please, this necessity of the country's existence?

The fact is that until scientific education has gone forward far beyond the point it has yet reached, until it has become a living force in the world of politics and statesmanship, we shall hardly escape the ruin of our country.

The business men will not save us; as has been said with much truth, the products of modern business methods are to a great extent slums and millionaires. It lies to a great extent with scientific men themselves to see that reform is forthcoming; and more power to the Guild of Science and to any other agency which can help to bring about this much-needed result.

While scientifically educated men, whether doing special work or acting as officers, have been held of far slighter account in the services than they ought to have been, for physicists as such there has been little or no recognition, except, I believe, when they happened to be ranked as research chemists! How did this happen? Why, the various trades asserted themselves, and the result was a sufficiently long list of 'reserved occupations,' a list remarkable both for its inclusions and for its exclusions. There was, for example, a class of 'opticians,' many of whom have no knowledge of optics worth mentioning. They are merely traders. One of these, for example, the proprietor of a business, made a plaintive appeal to myself as to how he could determine the magnifying powers of certain field-glasses which he wished the Ministry of Munitions to purchase. But for a young scientific man, even if he were an eminent authority on theoretical and practical optics, but who was not in the trade, there was no place.

Research chemists received their recognition in consequence of the existence of the Institute of Chemistry. I am extremely glad to find that something is now being done to found an Institute of Physics. I hope this movement will be successful, and that it will be thoroughly practical and efficient. I hope its President and Council, its Members and its Associates, will be zealous for science, and especially for physics. It ought to be a thoroughly hard-working body, without any frills destitute of work value. Of honorary Members or honorary Fellows there should be none. There are enough of limelight spots for those who deserve and like that kind of illumination.

I am glad that something is being done at last for the organisation of scientific research. This movement has started well in several, if not in all, respects, and I wish it all success. There are, however, one or two dangers to be avoided, and I am not sure—I may be much too timid and suspicious—that they are fully recognised, and that the result will not be too much of a bureaucracy. Somehow or other I am reminded by the papers I have seen of the remark of a poor man who, asking charity of someone in Glasgow, was referred to the Charity Organisation Society of that city. 'No, thank you,' he said; 'there is a good deal more organisation than charity about that institution.' So I hope that in the movement on foot the organisation will not be more prominent than the science, and the organisers than the scientific workers.

There is to my mind too much centralisation aimed at. Everything is to be done from London: a body sitting there is to decide the subjects of research and to allocate the grants. There may be a good deal to be said for that in the case of funds obtained in London. But apparently already existing local incentives to research work are to be transferred to London. The Carnegie Trust for the Universities of Scotland, soon after its work began, inaugurated a scheme for research work in connection with these Universities. The beneficiaries of the Trust, it is well known, must be students of Scottish nationality. The action of the Trust has been most excellent, and much good work has been done. Now, so far as chemistry and physics are concerned, it has been proposed, if not decided, to hand over to the organisation in London the making of the awards, a process of centralisation that will probably not end with these subjects. I venture to protest against any such proceeding. The more incentives and endowments of research that exist and are administered in the provinces the better. Moreover, this is a benefaction to Scottish students which ought not to be withdrawn and merged in any provision made for the whole country, and administered in London by a bureau which may know little of the Scottish Universities or of Scottish students. The bureau might, with equal justice or injustice, be given command of the special-research scholarships of all the Universities both in England and Scotland, and administer them in the name of the fetish of unification of effort. I do not know, but can imagine, what Oxford and Cambridge and Manchester and Liverpool would say to that. But even Scotland, where of course we know little or nothing about education

of any kind, may also have something to say before this ultra-centralisation becomes an accomplished fact.

There is, it seems to me, another danger to be avoided besides that of undue centralisation in London. In most of the statements I have seen regarding the promotion of research work the emphasis seems to be on industrial research, that is in applied science. This kind of research includes the investigation of physical and chemical products of various kinds which may be used in arts and manufactures, and its deliberate organised promotion ought to be a commercial affair. I observed, by the way, with some amusement, that according to the proposals of one Committee for Applied Science, which is prepared to give grants and premiums for researches and results, the Professor or Head of a Department, from whom will generally come what are most important, the ideas, is to have no payment. He is supposed to be so well paid by the institution he belongs to as to require no remuneration for his supervision of the Committee's researches. And the results are to be the sole property of the Committee!

There is in this delightfully calm proposal at least a suggestion of compulsion and of interference with institutions and their staffs, which ought to be well examined. Also some light is thrown on the ideas of such people as managing directors of limited liability companies, who are members of such a committee, as to what might reasonably be expected of men of high attainments and skill, whose emoluments taken all round are on the whole miserably insufficient.

I think that it is in danger of being forgotten that, after all, pure science is by far the most important thing. Most of the great applications of science have been the products of discoveries which were made without any notion of such an outcome. Witness the tremendous series of results in electricity of which the beginning was Faraday's and Henry's researches on induction of currents, and the conclusion was the work of Hertz on electric waves. From the first came the production and transmission of power by electricity, from the last the world has received the gift of wireless telegraphy. I am not at all sure whether the great men who worked in the sixty or seventy years which I have indicated would have always received grants for proposed researches, which to many of the good business directors and other supermen serving on a great bureau of investigation, had such then existed, would have appeared fantastic and visionary. In research, in pure science at least, control will inevitably defeat itself. The scientific discoverer hardly knows whither he is being led; by a path he knows not he comes to his own. He should be free as the wind. But I must not be misunderstood. Most certainly it is right to encourage research in applied science by all available and legitimate means. But beware of attempting to control or 'capture' the laboratories of pure science in the Universities and Colleges of the country. Let there be also ample provision for the pursuit of science for its own sake; the return will in the future as in the past surpass all expectation.

I had intended to say something about scientific education as exemplified by the teaching of physics. I have left myself little time or space for this. I cannot quite pass the matter over, but I shall compress my remarks. In the first place I regard dynamics, especially rotational dynamics, as the foundation of all physics, and it is axiomatic that the foundation of a great structure should be soundly and solidly laid. The implications of dynamics are at present undergoing a very strict and searching examination, and now we may say that a step in advance has been taken from the Newtonian standpoint, and that a new and important development of dynamics has come into being. I refer of course to the new theories of relativity, which are now attracting so much attention. I hope to learn from the discussions, which we may possibly have, something of the latest ideas on this very fundamental subject of research. It is a matter for congratulation that so many excellent accounts of relativity are now available in English. Some earlier discussions are so very general in their mathematical treatment and notation as to be exceedingly difficult to master completely. I have attacked Minkowski's paper more than once, but have felt repelled, not by the difficulties of his analysis, but by that of marshalling and keeping track of all his results. Einstein's papers I have not yet been able to obtain. Hence it is a source of gratification to have Professor Eddington's interesting Report to the Physical Society and the other excellent treatises which we have in English.

But continual thought and envisaging of the subject is still required to give anything approaching to instinctive appreciation such as we have in ordinary Newtonian dynamics. I venture to say that the subject is pre-eminently one for physicists and physical mathematicians. In some ways the new ideas bring us back to Newton's standpoint as regards so-called absolute rotation, a subject on which I have never thought that discussions of the foundations of dynamics had said absolutely the last word. Some relativists would abolish the ether, I hope they will not be successful. I am convinced that the whole subject requires much more consideration from the physical point of view than it has yet received from relativists.

The better the student of physics is grounded in the older dynamics, and especially in the dynamics of rotation, the sooner will he be able to place himself at the new point of view, and the sooner will his way of looking at things begin to become instructive.

With regard to the study of physics in our Universities and Colleges, I had written a good deal. I have put that aside for the present, and will content myself with only a few general observations. First, then, it would, I think, be conducive to progress if it were more generally recognised that dynamics is a physical subject, and only secondarily a mathematical one. Its study should be carried on in the departments of physics, not in those of mathematics or in separate departments of applied mathematics. It is, or ought to be, essentially a subject of the physical lecture-room and the physical laboratory. It belongs in short to *natural philosophy*, but not to physics divorced from mathematics, nor to the arid region of so-called applied mathematics, where nothing experimental ever interrupts the flow of blackboard analysis. The student should be able to handle rotating bodies, to observe and test the laws of precession and nutation, to work himself, in a word, into an instinctive appreciation of at least the simpler results of rotational theory. He should learn to think in vectors, without necessarily referring either to Hamilton or to Grassmann. Some people appear to censure the use of vector ideas without the introduction at the same time of some form of vector notation. I cannot agree with them. Personally I do not feel drawn to any system of vectors in particular—all have their good points, and in some ways for three dimensional work the quaternion analysis is very attractive—but vector *ideas* are of the very utmost importance.

Hence I deprecate the teaching, however elementary, which as a beginning contents itself with rectilineal motion. The true meaning of rate of change of a directed quantity, even of velocity and acceleration, is missed, and instead of having laid a foundation for further progress the teacher, when he desires to go beyond the mere elements, has not merely to relay his foundations, he has in fact to extract imperfect ideas from his pupils' minds and substitute new ones, with the result that a great deal of avoidable perplexity and vexation is produced. The consideration of the manner of growth of vectors—the resultant vector or it may be component vectors, according to convenience—is the whole affair. As a simple illustration of what I mean, take this: A vector quantity has a certain direction, and also a magnitude L. It is turning in a certain plane with angular speed ω. This turning causes a rate of production of the vector quantity about a line in that plane and perpendicular to the former, and towards which the former is turning, of amount $L\omega$. Thus a particle moving in a curve with speed v has momentum mv forwards along the tangent at the position of the particle. The vector is turning towards the principal radius (length R) of curvature at the point at rate v/R. Hence towards the centre of curvature momentum is growing up at time rate mv^2/R.

Dealt with in this way, with angular momentum instead of simple momentum, the motions of the principal axes of a rigid body give the equations of Euler instantly and intuitively, and all the mind-stupefying notions of centrifugal couples, and the like, are swept away.

With regard to mathematics, the more the physicist knows the better, and he should continually add to his store by making each physical subject he takes up a starting-point for further acquisition. Some very philistine notions as to mathematics prevail, and are very mischievous. For example, I once heard an eminent practical engineer declare that all the calculus an engineering student requires could be learned in an hour or two. This is simply not true, nor is it true, as some exponents of ultrasimplicity seem to suggest, that the profes-

sional mathematical teacher wilfully makes his subject difficult in order to preserve its esoteric character. Like the engineer or physicist himself, he is not always so simple as he might be; but the plain truth is that no good progressive mathematical study can be carried out without hard and continued application of the mind of the student to the subject. And why should he depend on the mathematical teacher? Let him be his own teacher! There are plenty of excellent books. If he has a determination to help himself he will, if he makes a practice of reserving difficulties and returning to them, find them vanish from his path. Let him also cultivate the power of giving attention, and he will both understand and remember.

As I have said, I am specially interested in rotational dynamics. In the course of the war I have been appalled by the want of appreciation of the principles of this subject, which, in spite of considerable acquaintance with the formal theory, seemed to prevail in some quarters. I don't refer to mistakes made by competent people—it is human to err—but to the want of appreciation of the true physical meaning of the results expressed by equations. A gyrostat as ordinarily considered is a closed system, and its dynamical theory is of a certain kind. But do away with the closedness, and the dynamical theory is quite a different affair. Take, as an example, the case of two interlinked systems which are separately unstable. This compound system can be made stable even in the presence of dissipative forces. A certain product of terms must be positive, so that the roots of a certain determinantal equation of the fourth degree may all be positive. The result shows that there must be angular acceleration, not retardation, of the gyrostat frame. This acceleration is a means of supplying energy from without to the system, the energy necessary to preserve in operation the functions of the system.

I have ventured to think this stabilising action by acceleration of the compound motion very important. It is lost sight of by those who consider and criticise gyrostatic appliances from the usual and erroneous point of view. Also I believe that it is by analogy a guide to the explanation of more complicated systems in the presence of energy-dissipating influences, and that the breaking down of stability or *death* of the system is due to the fact that energy can no longer be supplied from without in the manner prescribed for the system by its constitution.

I had just concluded this somewhat fragmentary address when the number of *Nature* for July 24 came to hand, containing a report of Sir Ernest Rutherford's lecture at the Royal Institution on June 6. The general result of Sir Ernest's experiments on the collision of α-particles with atoms of small mass is, it seems to me, a discovery of great importance, whatever may be its final interpretation. The conclusion that 'the long-range atoms arising from the collision of α-particles with nitrogen are not nitrogen atoms, but probably charged atoms of hydrogen or atoms of mass 2,' is of the utmost possible interest. The α-particle (the helium atom, as Rutherford supposes it to be) is extraordinarily stable in its constitution, and probably consists of three helium nuclei each of mass 4, with two attached nuclei of hydrogen, or one attached nucleus of mass 2. The intensely violent convulsion of the nitrogen atom produced by the collision causes the attached nuclei, or nucleus, to part company with the helium nuclei, and the nitrogen is resolved into helium and hydrogen.

It seems that, in order that atoms may be broken down into some primordial constituents, it is only necessary to strike the more complex atom sufficiently violently with the proper kind of hammer. Of course, we are already familiar with the fact that radio-active forces produce changes that are never produced by so-called *chemical* action; but we seem now to be beginning to get a clearer notion of the *rationale* of radio-action. It seems to me that it might be interesting to observe whether any, or what kind of, radiation is produced by the great tribulation of the disturbed atoms and continued during its dying away. If there is such radiation, determinations of wave lengths would be of much importance in many respects.

I may perhaps mention here that long ago, when the cause of X-rays was a subject of speculation, and the doctrine that mainly found acceptance was that they were not light waves at all, I suggested to the late Professor Viriamu Jones that radiation of extremely small wave length would be produced if

atomic or molecular vibration, as distinguished from what in comparison might be called molar vibration, could be excited. An illustration that suggested itself was this : Take a vibrator composed of a series of small masses with spring connections. If these masses are of atomic or molecular dimensions any ordinary impulse or impact would leave them unaffected, while vibrations of large groups of them, vibrations depending on the connections, would result. But the impact on one of the masses of a hammer of sufficiently small dimensions and mass would give vibrations depending on the structure of the mass struck, and independent of the connections, just as the bars of a xylophone ring, while the suspended series of bars, if it swings at all, does so without emitting any audible sound. This is, I believe, in accordance with the theory now held as to X-rays. We now have some information as to the mode of producing a local excitement so intense as to cause not merely atomic disturbance, but actual disruption of the atomic structure. Further developments of Sir Ernest Rutherford's experiments and of his theory of their explanation will be eagerly awaited.

The following Reports and Papers were then read :

1. *Report of Committee on Radiotelegraphic Investigations.*
See Reports, p. 40.

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2. *The Spectrum of Nova Geminorum.*
By F. J. M. Stratton, *D.S.O., M.A.*[1]

The following types of spectrum occur in the course of the star's history : (1) An absorption spectrum of hydrogen and enhanced lines of calcium, iron, and titanium, displaced towards the violet by amounts varying on different dates between 0.0035λ and 0.0005λ. (2) An absorption spectrum of hydrogen, oxygen, nitrogen, carbon, and helium displaced towards the violet by amounts varying on different dates from 0.0061λ to 0.0027λ. (3) A spectrum of bright bands corresponding to both sets of lines represented in the absorption spectrum. The bands were generally about 24 tm. wide, were slightly displaced to the red, and appeared later than the corresponding absorption lines. For some elements these bands were flanked by faint wings at each end, giving a wider band of double the width. In the bright central band two maxima appeared which for hydrogen varied in brightness with the strength of the two absorptions. (4) A bright band spectrum, consisting of hydrogen and helium lines and the nebulium lines known in the planetary nebulæ. The structure of the bright bands is maintained unaltered, the same maxima showing as in stage (3). (5) A bright band spectrum, with the nebulium giving place to the lines typical of the bright-line Wolf-Rayet stars.

In addition, there are present in the early stages certain undisplaced narrow dark lines, notably D_1, D_2 of sodium and H and K of calcium. All structure in the bright bands and displacements of dark lines of an element vary directly as the wave-length of the presumed source; velocity is the only physical cause which seems capable of producing the results. The velocities are so large, reaching up to 2×10^8 cm./sec., that electrical causes are suggested for them. The sequence of spectral type from heavy elements to light ones and the maintenance of a common structure in the bright bands for many months after the initial changes seem typical of all Novæ, but the structure of these bands is different for each Nova.

[1] To be published in *Annals of Solar Physics Observatory, Cambridge*, Vol. 4. See also *Monthly Notices, R. Astronomical Soc.*, Vols. 73, 79.

3. *The Progressive Spectra of Nova Aquilæ.* 1918-19.

By the Rev. A. L. Cortie, *S.J., F.R.A.S.*[2]

The present paper gives a general account of the changes in the spectrum of Nova Aquilæ, between the dates June 10 and October 23, 1918, and in July, August 1919. Measurements and comparisons of the earlier plates lend little, if any, countenance to the view that a spectrum of the G, or solar type, was present in the ultra-violet regions of the spectrum. The broad dark bands observed in this part of the spectrum were mainly due to the doubling of the dark hydrogen series, and the superposition with decreasing wave-length of members of the second series over those of the first, on account of their relative displacements. The blends so formed probably contained also enhanced lines of titanium, vanadium, and calcium, found in the spectrum of α Cygni.

There is more evidence for a spectrum of the Procyon, or F type, in the ultra-violet spectrum of the Nova in its earlier stages. The K line of calcium, and the Hη line of hydrogen, with which possibly is blended a magnesium line, bear a greater likeness to Procyon than to α Cygni. But, with these exceptions, the dark line spectrums of the Nova, even in the ultra-violet, exactly matches that of α Cygni, the great majority of the lines in the spectrum of which are characteristic of the solar chromospheric spectrum.

Although the increase in brilliancy of the star in its earlier life-stages was rapid, 2·41 magnitudes in 24 hours, yet it was not much greater than that of some variable stars; e.g. R. Ursæ Maj., 1·87 mag., and S.S. Cygni, 1·97 mag. per 24 hours.

The whole of the hydrogen series of dark lines was represented in the spectrum, which extended very far into the ultra-violet. These dark hydrogen lines were doubled, and greatly displaced. The displacements were proportional to wave-length. These dark lines were accompanied on their more refrangible sides by broad bright bands, about 50 A.U. in average width. The bright red band of hydrogen was by far the brightest in the early stages of the spectrum. A normal spectrum of α Cygni fits the centres of these bright bands. This entails that the dark hydrogen lines were displayed with a velocity of approach of the order of 1700 km/sec for the first set, and 2400 km/sec for the second set, twice and thrice respectively the velocity of the quickest moving solar prominences. The dark line α Cygni spectrum was displaced concomitantly with the first set of hydrogen lines.

The regularly decreasing widths of the hydrogen bright bands with decreasing wave-length indicates also velocity in the line of sight. These bright bands were very complicated in structure in the earlier spectra, but by June 15 showed a definite triple character, which was maintained until they began to fade away at the end of August 1918. That is, for about five months they maintained their relative widths and displacements, of the order of 1300 km/sec approach, and 1200 km/sec recession. The spectrum represented by the middle members of the triple bright bands remained stationary. The long continuance of the widths and great velocities of these bright bands present a great difficulty for any explanation based on a motion in the line of sight. Is it possibly a Zeeman magnetic effect?

By June 15 the spectrum was almost entirely a bright band spectrum of the α Cygni or A type. The bright bands were in many cases doubled, notably in the band λ 4640, which is a nebula band appearing thus early in the spectrum. This band grew in intensity until the end of August.

By the end of July 1918 the bright band α Cygni spectrum had become very faint, which phase was accompanied by the brightening of a bright band γ Orionis, or B type spectrum, chiefly helium lines. The brighter nebula lines were also very prominent.

After August 23 the predominant type of spectrum was that of a planetary nebula. The chief nebula and O-type star lines were relatively much the stronger. But the γ Orionis lines remained until at least October 23; helium, oxygen, nitrogen. Some α Cygni lines also still faintly subsisted; e.g. titanium.

[2] See *Observatory*, Oct. 1919, Vol. 42, No. 544, pp. 366, 367.

The star was again observed in July and August 1919. Visually it showed a planetary nebula disc surmounting a bright stellar point. Its usual spectrum too was concentrated in a single green line λ 5007. The photographic spectrum showed in addition λ 4363 very prominently, and other nebula lines faintly.

The sequence of progressive changes was therefore from a possible Procyon type spectrum (FSG) through an α Cygni spectrum (A2F.p.), and a γ Orionis spectrum (B^2), to that of a planetary nebula. This sequence is in agreement with that generally adopted for giant stars rising in temperature. But in the Nova it was accompanied by a gradual lowering in magnitude, and presumably of temperature. The nebula was therefore most probably present at the very beginning of the changes. A solar eruption on a magnified scale in a giant star situated in a dark nebula would square with the observed spectral changes. The nebula would be put into sympathetic luminous vibration by the eruption. The α Cygni lines are chromospheric lines. The displaced hydrogen is characteristic of such eruptions. The γ Orionis, the O-type star and nebula lines belong to the nebula in which the eruption took place.

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4. *Report on Wave Motion.* *By* Sir G. Greenhill, *F.R.S.*
See p. 403.

WEDNESDAY, SEPTEMBER 10.

Discussion on Thermionic Tubes.

The following Papers were read :—

Discussion on Thermionic Tubes, opened by Professor W. H. Eccles, *D.Sc.*

Professor Eccles gave a general description of the history and development of the three electrode valve, and explained its rectifying property and its uses in amplifiers, heterodyne reception, and the arrangements necessary to produce continuous waves. Experiments were shown illustrating these uses of the valve, and the way was thus prepared for the discussion of special points by subsequent speakers. Professor Fortescue drew attention to the functions and properties of the various parts of the valve in some detail. The hot filament is the source of the electrons upon which the action of the valve fundamentally depends, and with tungsten filaments as at present used only 4½ per cent. of the energy heating the filament is usefully employed as electron emission. This efficiency might be improved by using oxide-coated filaments or higher temperatures, but at present neither of these methods has been entirely successful in practice. The construction of the grid and the question of freeing the anode and containing vessel from occluded gas were also discussed, and the importance of investigating the methods of removing the last traces of gases and examining their nature was emphasised. Dr. Whiddington drew attention to the possibility of using valves and oscillating circuits for making many standard physical measurements. Thus, for instance, the coefficient of mutual induction between two coils can be measured by determining the degree of coupling at which oscillations are just started and maintained in the valve circuit. He also alluded to Professor Eccles' example of the extreme sensitiveness of heterodyne reception as represented by the effect of passing coal gas between the plates of a condenser in an oscillating circuit. The temperature coefficient of resistance, the conductivity of flames, the permeability of liquids and other quantities could also be measured by this delicate method.

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1. *A Wireless Method of Measuring e/m.*

By R. WHIDDINGTON, *M.A., D.Sc.*[1]

It is well known that if inductance capacity circuits of low resistance be associated with a three electrode thermionic valve in the manner shown in fig. 1, oscillations may be set up in the anode circuit having a period $2\pi\sqrt{LC}$ (very nearly), providing that

(1) The resistance R of the anode circuit is small.

(2) The 'resistance' ρ of the valve is great.

(3) The mutual induction M between the grid and anode coils is only just great enough to maintain the oscillations, a condition approximately realized when $M > \frac{1}{k}\left(\frac{L}{\rho} + RC\right)$.

In the arrangement of fig. 1, which represents a typical oscillation circuit, the ionic flow within the valve pulsates at a frequency determined by the values of the inductance and capacity associated with the anode circuit.

This method of producing oscillations has been very largely used for many purposes, particularly in wireless telegraphy and telephony, and in modern practice is usually employed in conjunction with 'hard' valves—that is to

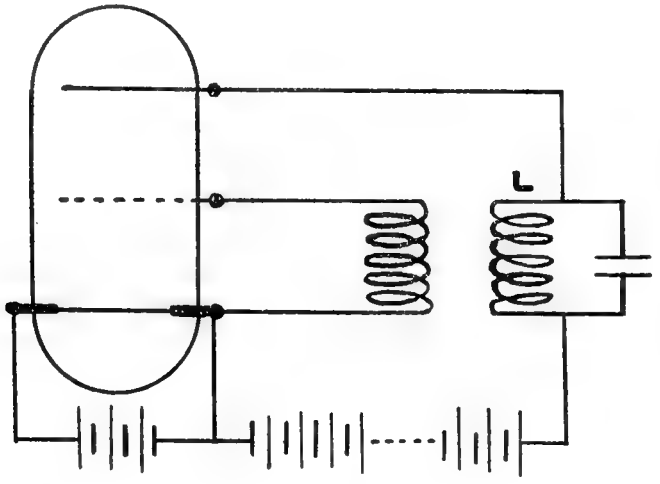

FIG. 1.

say, valves from which gas and vapour have been removed to such a degree that ionisation by collision is negligible.

The arrangement of fig. 1 can be used equally successfully, however, and usually more efficiently with 'soft' valves—that is to say, valves containing small quantities of gas or vapour so that ionisation by collision can occur.

It is the object of this short paper to show that in the case of soft valves a simpler scheme than the one just outlined—and, moreover, one involving entirely different principles—can be used to produce oscillations. This new arrangement is represented in fig. 2.

There are in this arrangement no capacity inductance circuits, as in fig. 1, but simply a non-inductive potentiometer device in the grid circuit and a constant source of high potential in the anode circuit.

It is found in practice that quite strong oscillations can be produced, of a frequency dependent almost altogether on the grid potential and geometrical dimensions of the valve electrodes.

It will be convenient at this stage to outline a simple theory which explains broadly the observed phenomena.

[1] See *Radio Review*, Nov. 1919.

An assumption that has to be made at the outset is that, although one filament as a whole is emitting electrons continuously according to the accepted exponential temperature law, yet there are often one or more spots which are emitting with exceptional power. Such spots in the case of a tungsten filament are probably of chemical origin, due to the presence of local impurity, and would be very sensitive to small changes of temperature. In the theory to be developed it is supposed that the bombardment by positive ions of the filament in the neighbourhood of such an emitting spot would greatly increase the local electronic emission so long as the bombardment lasted. Very direct

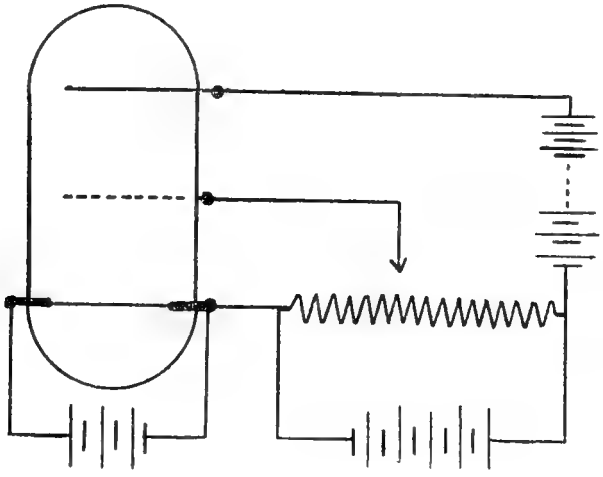

FIG. 2.

evidence of the existence of such selectively emitting spots on a tungsten filament is afforded by the experience of manufacturers of hard valves. It is customary in the factories to 'clean up' the anode by passing a heavy thermionic discharge through the valve when on the pump. The dissipation of energy at the anode is regulated to such a point that the metal of the anode is maintained at a cherry-red heat. During this process it is frequently observed that one or more points on the anode are very much hotter than the main surface, a fact which can only be explained on the assumption that there is exceptionally powerful emission from the corresponding points on the hot filament.

Consider one of these spots on the filament. If a burst of electrons be emitted they proceed towards the filament with a speed u given by

$$\tfrac{1}{2} m u^2 = Ve; \quad \text{or, } u = \sqrt{2 V . e/m}$$

where e/m is the charge to mass ratio for the electron and V is the positive grid potential with respect to the particular point on the filament considered.

(It is assumed as an approximation that the filament is screened from the anode by the grid, approximately true for the particular type of valve used in the experiments, which had a fine-meshed grid.)

The electrons will thus take a definite and calculable time to travel from filament to grid under the moderate potential applied. On passing through the grid, however, the electrons emerge into a strong electric field and assume ionising speed. The negative ions produced follow the electrons to the anode, but the positive ions pass back through the grid towards the filament with speed

$$u_1 = \sqrt{2 V . e/m_1}$$

where e/m is in this case the charge to mass ratio of the atom or molecule concerned.

There will thus be a cloud of positive ions focussed on the filament and

bombarding the original electron emitting spot. This bombardment produces a new burst of electrons, and so a self-sustaining current oscillation may be set up, the period of which depends on the applied grid potential.

The following table shows what frequency and wave-length of oscillation would be expected from the above general theory in the case of a valve with cylindrical gauze grid 6 millimetres in diameter and an axial hot wire. The singly-charged ions of hydrogen and mercury are there worked out for a grid potential of 1 volt.

Nature of Charged Particle	e/m (approximate)	u (cms/sec)	n (cycles/sec)	Wave-length (metres)
Electron . .	$1{\cdot}7 \times 10^7$	6×10^7	$4{\cdot}0 \times 10^8$	0·77
Hydrogen Atom.	10^4	$1{\cdot}4 \times 10^6$	$1{\cdot}0 \times 10^7$	30
Mercury Atom .	50	$1{\cdot}0 \times 10^5$	$6{\cdot}6 \times 10^5$	450

In actual experiments it was found that the arrangement of fig. 2 usually radiated energy at a frequency varying between 7.0×10^5 and 4.0×10^5 cycles. The wave-lengths (from which the frequencies were deduced) were measured by means of a heterodyne wave-meter in the vicinity.

The oscillations may therefore be safely ascribed to mercury vapour. It is to be observed, however, that the above calculated frequencies are based on singly-charged monatomic molecules, and that the frequency 6.6×10^5 cycles corresponds to the monatomic mercury molecule. If polyatomic molecules are involved the frequencies to be expected would be $1\sqrt{2}$, $1\sqrt{3}$, $1\sqrt{4}$, etc., times 6.6×10^5 cycles.

In the following table are shown the frequencies to be expected theoretically, and for comparison those actually observed.

Number of atoms in Molecule	Theoretical Frequency	Observed Frequency
1	6.6×10^5	$6{\cdot}4 \times 10^5$
2	4.7×10^5	$4{\cdot}5 \times 10^5$
3	3.8×10^5	$3{\cdot}5 \times 10^5$
4	3.3×10^5	—

Oscillations in addition to the above have been detected, believed to be due to the oxygen and carbon dioxide molecules, but have not yet been investigated in detail.

Referring back to the formula, it will be seen that the square of the speed of the ions (and therefore the square of the oscillation frequency) should be proportional to the potential applied to the grid.

This prediction is amply borne out in practice (the frequency of oscillation)^2 plotted against the grid potential yielding in all cases so far studied an excellent straight line. These lines cut the axis of potential at points determined partly by the position of the emitting spot on the filament and partly by the natural velocity emission of the electrons. This is a point which is being investigated in further detail, particularly from the point of view of getting a more accurate value for the ratio e/m than has hitherto been found possible.

2. *The Diffraction of Electric Waves.* *By* G. N. Watson, *Sc.D., F.R.S.*

The theory of the fundamental mathematical problem presented by long-distance wireless telegraphy has been investigated by Poincaré, Nicholson, Macdonald, Love, and by some of Sommerfeld's pupils, on the hypothesis that the earth consists of a sphere of high conductivity surrounded by dielectric. The results obtained are not obviously consistent, and they do not agree with experimental results. I have recently obtained a general formula whereby the theoretical results can be reconciled, and this formula shows that the magnetic force at angular distance and from the transmitter is roughly proportional to $\exp(-23{\cdot}94\ \theta/\sqrt{\lambda})$, where λ is the wave-length in kilometres. The experimental result obtained by Austin is $\exp(-9{\cdot}6\ \theta/\sqrt{\lambda})$. In order to obtain this result (which is obviously inconsistent with the result of the diffraction theory) by mathematical reasoning, I have investigated by my method the Heaviside-Eccles hypothesis that the upper regions of the atmosphere act as a conductor, and Austin's formula is exactly obtained if

$$h^2\sigma = 1{\cdot}67 \times 10'',$$

where h is the height in kilometres of the conducting layer above the surface of the earth and σ is the conductivity of the layer in rational units. If $h=100$, this formula gives the layer a conductivity of about 3·5 times the conductivity of fresh water. The mathematical investigations are given in detail in two papers, *Proc. Royal Soc.* 95A, and also in a paper by Dr. van der Pol in the *Phil. Mag.*, September 1919.

In the course of discussion of the above paper, Dr. B. van der Pol said :—

I consider that the mathematical work of Macdonald, Nicholson, and Watson does not leave the slightest doubt that the propagation round the earth of wireless waves cannot be explained by means of pure diffraction only.

As expounded by Prof. Watson, numerical agreement with experiments can be obtained when a concentric spherical shell having a certain conductivity is supposed to surround the globe. This shell was taken for mathematical reasons to have a sharp inner boundary. Such a boundary can hardly be expected to exist in the upper atmosphere, and it is likely that in a transition region considerable amounts of energy will be dissipated. When, however, regard is taken of the equation of motion of free ions in an alternating field, as indicated by Professor Eccles several years ago, it appears that the medium has not only a finite conductivity, but also an apparent diminution of the dielectric constant ϵ must occur.

In some experiments carried out at the Cavendish Laboratory, Cambridge, I have used as ionised medium the negative glow of a glow discharge, and waves were sent through it. Results were obtained confirming the above view. As this diminution of ϵ with height causes the wavefront to fall over in the direction of propagation, and is therefore favourable to wireless transmission, it is not unlikely that, when this increase of phase velocity with height is taken into account, the propagation of waves round the earth can be explained with the assumption of a *gradual* variation with height of conductivity *and* apparent dielectric constant.

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3. *On a possible Theory of Vision.* *By* Sir Oliver Lodge, *F.R.S.*

A resonance view of the action of the retina has long been in contemplation. The present writer pointed out in *Nature* for March 1890 that the rods and cones were of reasonably right dimensions to respond, like Hertz resonators, to transverse vibrations falling on their ends with the frequency of luminous waves. (See also *Modern Views of Electricity*, § 157A and fig. 60.)

But this gave no indication of how the nerves were thereby stimulated. The subsequent discoveries of excited radioactivity, and of the astronomical structure of an atom, give a hope of a more detailed theory.

An atom with K,L,M orbits is known to respond to K,L,M frequencies of X radiation, and to be ionised thereby.

Outlying electrons, such as are often held responsible for chemical or molecular processes, could respond to lower frequencies characteristic of visible light.

And if the orbital radius is estimated which shall enable an electron to respond to red, green, or violet light, the order of magnitude is not much larger than the atomic size 10^{-8} centimetre, even for heavy atoms. The necessary radius varies as the cube root of Moseley's atomic number, and with the two-thirds power of the wave length.

The suggestion is that the retina may be found to contain atoms in such a condition of incipient instability ('sub-generative,' as Professor Eccles calls the state of certain wireless 'valves') as to be readily excited by cumulative impulses of the right luminous frequency, and thereby to be stimulated so as to expel an electron and excite a nerve. The energy of expulsion could only be attributable to the incident light on the principle of syntonic accumulation—the ionisation-energy might be represented as hn—and so the extreme sensitiveness of the eye would be accounted for. The atom would be an amplifier or relay, able to respond to the faintest vibration of the right frequency. Retinal fatigue and other phenomena of vision could also be accounted for.

If, however, vision is tri-chromic, the tuning must not be too precise, the responders must be somewhat damped so as to respond over a fair range; and in the current *Phil. Mag.* (September 1919) Professor Barton, of Nottingham, claims to have shown by mechanical experiments on damped pendulums that three suitably damped and connected vibrators will exhibit phenomena which by an effort may be regarded as analogous to colour-vision.

Whether three varieties of vibrator are sufficient, or whether more are necessary, makes no difference to the present communication, which is intended to suggest to physico-physiological experimenters the attempt to examine whether chemical substances can be found in a recently removed retina which are able to emit high-speed electrons when subjected to light.

THURSDAY, SEPTEMBER 11.

The following Papers and Reports were read :—

1. *The Ionisation of Argon and Helium by Electron Collisions.* *By* Professor F. Horton *and* Miss A. C. Davies.[1]

Experiments were described showing that there are two critical velocities for electrons in both Argon and Helium. At the lower critical velocity, radiation is produced from the gas; at the higher critical velocity ionisation of the gas takes place. In the case of Argon these velocities correspond to potential differences of 11·5 volts and 15·1 volts respectively, and in Helium to potential differences of 20·4 volts and 25·6 volts respectively. From the values found for the ionisation velocities the high-frequency limits of the spectra of the two gases were calculated by applying the quantum relation $eV = hn$ and it was shown that these limits agree with those recently determined spectroscopically by Lyman.

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2. *The Production of Luminosity in Helium by Electron Collisions.* *By* Professor F. Horton *and* Miss D. Bailey.[2]

Helium atoms were bombarded by electrons, the velocity of which was gradually increased until luminosity was produced in the gas. It was found that the electron velocity could then be decreased slightly and the luminosity maintained. Experiments were made to determine the least velocity of the

[1] Partly published in *Proc. Roy. Soc.* A, vol. 95, p. 408. Remainder to be published in the same.

[2] To be published in *Phil. Mag.*

electrons which sufficed to maintain the luminosity, and observations were made to ascertain whether the different series of lines in the Helium spectrum required different electron velocities for their production. It was found that luminosity was never produced until the electron velocity was about 25 volts, and that it could not be maintained at velocities lower than 23 volts, and then only in the presence of traces of impurity. No evidence was obtained that any one of the Helium series could be excited without producing the others also.

3. *The Æther and the Perihelion of Mercury.* *By* Dr. R. A. Houstoun.[1]

It is well known that the perihelion of Mercury advances some 42 seconds of arc per century, and that this progression has been explained by Einstein on his theory of generalised relativity. Sir Oliver Lodge attempted to explain it by assuming that the mass of Mercury was given by $m_0/(1-v^2/c^2)^{\frac{1}{2}}$, where v was the velocity of mercury relative to the æther, the æther being at rest in space, the same law of variation as holds for the mass of a cathode particle, but his attempt was unsuccessful. I recently[1] suggested that the optical difficulties associated with the earth's motion through space were best met by assuming that the æther to the uttermost corners of space had the same velocity of translation as the earth had, by making it, in fact, geocentric. This suggestion leads to a very interesting result as regards the perihelion of Mercury.

For if we use Eddington's equation for the orbit,

$$\frac{d^2u}{d\theta^2}+u=\frac{F/m_0}{h^2u^2}\frac{m}{m_0},$$

and Sir Oliver Lodge's expression for the mass, but regard v as the velocity of Mercury *relative to the earth*, since according to my view the æther moves with the earth, the problem reduces to Newton's revolving orbit, and we find that the perihelion rotates a fraction of a revolution equal to

$$\frac{2\pi^2a^2}{c^2T^2(1-e^2)}$$

while the planet moves through one revolution. This expression is the same as Einstein's, except that he has the factor 12 instead of 2. Hence, if the mass of Mercury varied six times as fast as the mass of a cathode particle, we would have perfect agreement.

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4. *The Interpretation of the Quantum.* *By* Dr. R. A. Houstoun.

Planck's theory of radiation assumes that a certain quantity of energy $h\nu$, the quantum, is associated with radiation of frequency ν. This quantum is alleged to be inexplicable on the basis of Newtonian mechanics and has given rise to much theorising of a revolutionary nature; it seems to have altogether escaped notice, that it can be quite tolerably explained by the ordinary model atom which some of us use in our lectures.

This model atom consists of a sphere of positive electricity of uniform density ρ, the radius of the sphere being a. Inside the sphere there is one electron, which oscillates about its centre through the positive electricity. Let ν be the frequency (reciprocal of the period) of the oscillations, and suppose that the radius of the sphere is just large enough for the positive electricity to neutralise the electron. Then

$$\nu=\sqrt{\left(\frac{\rho e}{3\pi m}\right)} \text{ and } e=\frac{4}{3}\pi a^3\rho.$$

The sphere is supposed to be rigid.

Now suppose that the electron starts from rest on the surface of the sphere and falls towards the centre of the atom. Let v be the velocity acquired by the time it reaches the centre. Then $v=2\pi a\nu$. On eliminating ρ and a these three relations give

$$v=\left(\frac{2\pi e^2}{m}\right)^{\frac{1}{6}}\nu^{\frac{1}{3}}.$$

[1] *Phil. Mag.*, Feb. 1919.

If an electron has one quantum kinetic energy, its velocity is given by

$$v = \left(\frac{2h}{m}\right)^{\frac{1}{2}} \nu^{\frac{1}{2}}.$$

The difference between the two formulæ for v amounts to the sixth root of v, an amount which would hardly matter if only the visible spectrum were in question, but is much too great when we take the X-ray region also into consideration. But there is a surprising numerical agreement. If we fix our attention on two wave-lengths, (i.) that of sodium in the visible spectrum and (ii.) the wave-length 10^{-8} cm. in the X-ray region, we find that the two expressions for v give, in the case of (i.) $9{\cdot}29 \times 10^7$ cms./sec., and $8{\cdot}64 \times 10^7$ cms./sec., and in the case of (ii.) $1{\cdot}68 \times 10^9$ cms./sec., and $6{\cdot}64 \times 10^9$ cms./sec., the second value in each case being given by the quantum formula. Thus, there is fair agreement for sodium, but the new formula gives only one-quarter of the correct value in the X-ray region. If we make the electron fall from infinity, or vary the law of density of the positive electricity, we can shift the point of exact numerical agreement along the spectrum, but the power of ν always remains the same.

However, the agreement, such as it is, is sufficient to make it probable, that the quantum is the amount of energy acquired by a free electron in falling into a void atom.

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5. *On Gauss's Theorem for Quadrature and the Approximate Evaluation of definite Integrals with finite Limits.* *By* Professor A. R. Forsyth, *F.R.S.*—See p. 385.

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6. *On certain Types of Plane Algebraic Curve.*
By Professor Harold Hilton.[1]

The equation of the most general plane algebraic curve of degree six with deficiency 1 or 0, having a triple point at which two linear branches have five or six-point contact, while a third linear branch has ordinary contact with them both, can be put in one of the forms

$$(u-\alpha y^2)(u-\beta y^2)(u-\gamma y^2) = k(xu-y^3)^2,$$
$$(u-\alpha y^2)(u-\beta y^2)(u-\gamma y^2) = kx^2u^2;$$

where α, β, γ are constants and u is written for $yz+x^2$.

If in these equations we put $k=1$ and divide through by y, we get the most general quintic curve of deficiency 1 or 0, whose double points all coalesce at a single double point.

In general all these double points are nodes; but one is a cusp, if one or all of α, β, γ are zero. The deficiency is zero, if $(\beta-\gamma)(\gamma-\alpha)(\alpha-\beta) = 0$; otherwise it is unity.

The properties of the curve may be investigated in two ways :—

(i.) The co-ordinates of any point on the curve may be expressed in terms of a parameter t by finding the intersections of the curve with $u=ty^2$.

(ii.) The curve may be transformed into the cubic

$$kx^2z = (y-\alpha z)(y-\beta z)(y-\gamma z)$$

by the birational transformation which replaces u by y^3/z and x by $x+z$ (or x in the case of the second of the equations).

7. *Some unsolved Problems of Canadian Weather.*
By Sir Frederic Stupart.

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[1] Will probably be published in *Rendiconti del Circolo Matematico di Palermo*. 1920.

8. *Report of Seismology Committee.*—See Reports, p. 35.

9. *Report of Committee on Gravity at Sea.*—See Reports, p. 83.

10. *Report on Seismology after the War. By* Dr. G. W. Walker, *F.R.S.*—See Reports, p. 32.

FRIDAY, SEPTEMBER 12.

The following Papers and Report were read, and Discussion took place :—

1. *Photographs taken at Principe during the Total Eclipse of the Sun, May 29th. By* Professor A. S. Eddington, *F.R.S., and* E. T. Cottingham, *followed by a Discussion on Relativity, opened by* Professor Eddington, *F.R.S.*

Professor Eddington gave an account of the observations which had been made at Principe during the solar eclipse. The main object in view was to observe the displacement (if any) of stars, the light from which passed through the gravitational field of the sun. To establish the existence of such an effect and the determination of its magnitude gives, as is well known, a crucial test of the theory of gravitation enunciated by Einstein. Professor Eddington explained that the observations had been partially vitiated by the presence of clouds, but the plates already measured indicated the existence of a deflection intermediate between the two theoretically possible values 0·87″ and 1·75″. He hoped that when the measurements were completed the latter figure would prove to be verified. Incidentally Professor Eddington pointed out that the presence of clouds had resulted in a solar prominence being photographed and its history followed in some detail; some very striking photographs were shown.

Following on this account Professor Eddington opened the discussion on relativity, and referred again to the bending of the wave front of light to be expected from Einstein's new law when the light passes near a heavy body. It should be possible to test experimentally this law, which demands that the speed of light varies as $1-2\,\Omega$ where Ω is the gravitational potential. He showed that whether Einstein's solution of the problem be correct or not, it has at any rate given a new orientation to our ideas of space and time. Sir Oliver Lodge regarded the relativity theory of 1905 as a supplement to Newtonian dynamics by the adoption of the factor $\left(1-\frac{v^2}{c^2}\right)$ and its powers necessitated by experimental results; but he did not consider this dependence of mass and length on velocity as entailing any revolutionary changes of our ideas of space and time, or as rendering necessary the further complexities of 1915. He compared the difficulties involved with the case of measuring temperature, defined in terms of a perfect gas, and made with gases which only approximate to this ideal state. Dr. Silberstein pointed out that Einstein's theory of gravitation predicts three verifiable phenomena, *i.e.*, a shift of spectral lines, the bending of light round the sun and the secular motion of the perihelion of a planet. In the neighbourhood of a radially symmetric mass, such as our sun, the line element ds is given by :—

$$ds^2=(1-2\mathrm{M}/c^2r)c^2dt^2-(1-2\mathrm{M}/c^2r)(dx^2+dy^2+dz^2).$$

The coefficient c^2dt^2 gives by itself a lengthening of the period of oscillation for a terrestrial observer in the ratio $(1+\mathrm{M}/c^2r) : 1$, demanding a shift of spectral lines of about ·01Å.U. Secondly, the path of rays of light is obtained by putting $ds=o$, and the first and second coefficients give jointly a bending which, for rays almost grazing the sun, is 1·75″. Thirdly, Keplerian motion is predicted with a progressively moving perihelion which in the case of Mercury turns out to be 43″ per century. He drew attention to the fact that St. John's results in 1917

showed no shift of the spectral lines, a fact which in itself would overthrow the theory in question. Father Cortie pointed out that Campbell's photographs, taken in 1918 and measured by Curtis, gave no trace of any displacement of the images of 43 stars distributed irregularly round the sun.

Spectrum Emission of Atomic Systems containing a Double or More Complex Nucleus. *By* L. SILBERSTEIN, *Ph.D.*

The subject proper of the paper is preceded by a short historical account of the work done since 1913 by Bohr, the pioneer of the quantum theory of spectra; by Sommerfeld (relativistic refinement of Bohr's theory leading to the fine structure of spectrum lines); and by Epstein (Stark effect).

In all these investigations the nucleus of the atom is assumed to be a homogeneous spherical charge, or, which is the same thing, a point charge. The corresponding spectra are all series of the Balmer type, $\frac{1}{\lambda} = \text{const.} \left(\frac{1}{m^2} - \frac{1}{n^2}\right)$ m and n being integers. These series consist, apart from relativistic refinements, of sharp (ideally monochromatic) lines.

In order to obtain series of other more complicated types, and, moreover, consisting of 'lines' which, even without taking into account the relativistic terms, will show a complicated fine structure, the author works out, on the lines of the quantum theory, the spectra emitted by atoms containing aspherical nuclei. As a first example the case of two fixed positive centres as nucleus is treated without restrictions of the dimensions of the electron's orbits. This being the famous soluble case of Euler and Jacobi, the author treats it by the method of separation of variables. A variety of orbits and of the corresponding types of spectrum series are described and illustrated in their general features. The sub-case of comparatively large orbits, which is physically the most interesting one, is treated, with all details, by the method of perturbations. If $2a$ be the mutual distance of the two centres, the negatived energy belonging to any stationary orbit, in three dimensions, is, up to $\left(\frac{a}{r}\right)^4$-terms,

$$W = \frac{\kappa N h c}{(n_1+n_2+n_3)^2}\left\{1+\gamma^2\frac{(n_1+n_2+n_3)^2}{(n_1+n_2)^6}F(n_1,n_2,n_3)\right\} \quad . \quad . \quad (1)$$

where κe is the total charge of the nucleus, N the Bohr expression of the Rydberg constant,

$$\gamma = \frac{\kappa N h c \alpha}{e^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

n_1, n_2, n_3 three independent integers, and

$$F = \frac{3}{2}\left(1-\frac{n_1^2}{(n_1+n_2)^2}\right)\left(1+\frac{3}{4}\epsilon^2\alpha\right)-\left(1+\frac{3}{2}\epsilon^2\right); \quad . \quad . \quad . \quad (3)$$

$n=n_1+n_2+n_3$; ϵ the eccentricity of the 'osculating' orbit, which is quantitized by the usual principles so that

$$\epsilon^2 = 1 - \frac{(n-n_3)^2}{n^2},$$

and finally α a number contained between 1 and 3, namely

$$\alpha = 1 + 2\sin^2 \delta, \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

δ being the longitude of the perihelion counted from the equatorial plane. For $\gamma=0$, the series corresponding to (1), is a Balmer series of sharp lines. The γ^2 term gives doublets, or triplets, etc., according to the value of $n_1+n_2+n_3$ in the constant term; moreover, each of the components of these doublets, etc., consists in general of several sub-components. Those corresponding to $n_2=0$ or $n_3=0$ are sharp, ideally monochromatic [these correspond to orbits contained in the equatorial plane or to any circular orbits]; all others have a

small but finite breadth, owing to $1 < \alpha < 3$. A few concrete examples are quoted, together with the distribution of the components and sub-components. If, say in the case of doublets, the frequency interval is to be such as that observed for the doublet Hα, formula (1), with (2), gives for the distance of the centres $2a = 3.10^{-12}$ cm.

In the next place, nuclei of any axially symmetric form are discussed and shown to lead to essentially similar results. Finally, the most general case of an arbitrarily shaped nucleus is investigated, when besides δ also the longitude of the node is shown to be a source of finite breadth of some of the sub-components; moreover, formula (1) is in all such cases replaced by a somewhat more complicated one.

The full paper will shortly be published in the *Philosophical Magazine*.

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3. *The Determination of the Viscosities of Liquids at High Pressures.*

By Dr. T. E. Stanton, *F.R.S.*

The method consists essentially of a system of two horizontal (the upper one of capillary dimensions) and two vertical tubes forming a closed circuit of liquid under pressure, the lower half of the circuit containing mercury and the upper half the liquid under test. The end of the system rests on a horizontal knife edge, and the other is carried by a spiral spring. On the mercury being displaced by a given amount, flow will take place round the circuit owing to the difference of head, and it is evident that if the spring be so designed that its rate of extensions is equal to the rate of change of head of the mercury, flow of the liquid under test will take place through the capillary tube under a constant pressure difference and at a velocity which can be calculated from the rate of extension of the spring. In this way all the data required for the determination of the absolute viscosity of the fluid are determined.

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4. *Wireless Telegraphy during the First Three Years of the War.*

By Major T. Vincent Smith, *M.C.*

This paper deals with wireless in what was the Military Wing of the Royal Flying Corps during the first three years of the war, and brings the history of this work up to the time of the amalgamation of the Royal Naval Air Service and Royal Flying Corps into the Royal Air Force.

It shows the state of knowledge at the beginning of the war, and the gradual progress made in the building up of an immense organisation.

It gives in detail the experiences of the early days, the difficulties which arose, and how they were met.

Improvements in apparatus, methods, etc., and their effect upon operations are shown, and the technical means by which the enemy was beaten are discussed.

The important work of the Royal Flying Corps in co-operation with Artillery, Infantry, and Cavalry would have been practically impossible without wireless. These things are discussed from their inception, and their progress followed from birth to maturity.

The introduction of thermionic values for transmission and reception, inter-aeroplane telephony, and directional wireless are touched upon, though the war ended before their influence had time seriously to affect the final operations.

The story is a collection of details, each one small in itself, but the combined whole shows how the many difficulties, inseparable from an ever-increasing demand, were overcome in a manner which earned the respect of the enemy.

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5. *The Limitations of Relativity.*

By W. J. Johnston *and* Sir Joseph Larmor.

The following propositions are believed to be valid, on the basis of a concise symbolic calculus, subject, of course, to critical verification.

(1) If a field of physical activity possesses the two characteristic properties

(i) that the quantities which define it are propagated through the æther with a single constant velocity, and (ii) that translatory uniform convection as a whole through the æther produces no modification in the field, then it is necessarily restricted to the special type of the electrodynamic field as formulated by Maxwell.

(2) A field of gravitation is included as the limiting form of such a type when the velocity of propagation becomes very great. As like source is now to attract like, the energy of the field must be kinetic and not elastic. The question of interaction between a field of gravitation and electric fields or rays of light is, of course, a separate and fundamental one, independent of theories of relativity, and is now being put to refined test by astronomical observation.

(3) If time were linked with space after the manner of a fourth dimension, relativity in electrodynamic fields would be secured as above, but the sources of the field could not be permanent particles or electrons. If physical science is to evolve on the basis of relations of permanent matter and its motions, time must be maintained distinct from space, and the effect of convection must continue to be thrown on to the material observing system in the form of slight modification of its structure.

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6. *How could a Rotating Body such as the Sun become a Magnet?* *By* Sir Joseph Larmor.

The obvious solution by convection of an electric charge, or of electric polarisation is excluded; because electric fields in and near the body would be involved, which would be too enormous. Direct magnetisation is also ruled out by the high temperature, notwithstanding the high density. But several feasible possibilities seem to be open.

(1) In the case of the sun, surface phenomena point to the existence of a residual internal circulation mainly in meridian planes. Such internal motion induces an electric field acting on the moving matter: and if any conducting path around the solar axis happens to be open, an electric current will flow round it, which may in turn increase the inducing magnetic field. In this way it is possible for the internal cyclic motion to act after the manner of the cycle of a self-exciting dynamo, and maintain a permanent magnetic field from insignificant beginnings, at the expense of some of the energy of the internal circulation. Again, if a sunspot is regarded as a superficial source or sink of radial flow of strongly ionised material, with the familiar vortical features, its strong magnetic field would, on these lines, be a natural accompaniment: and if it were an inflow at one level compensated by outflow at another level, the flatness and vertical restriction of its magnetic field would be intelligible.

(2) Theories have been advanced which depend on a hypothesis that the force of gravitation or centrifugal force can excite electric polarisation, which, by its rotation, produces a magnetic field. But, in order to obtain sensible magnetic effect, there would be a very intense internal electric field such as no kind of matter could sustain. That, however, is actually got rid of by a masking distribution of electric charge, which would accumulate on the surface, and in part in the interior where the polarisation is not uniform. The circumstance that the two compensating fields are each enormous is not an objection; for it is recognised, and is illustrated by radioactive phenomena, that molecular electric fields are, in fact, enormous. But though the electric masking would be complete, the two distributions would not compensate each other as regards the magnetic effects of rotational convection: and there would be an outstanding magnetic field comparable with that of either distribution taken separately. Only rotation would count in this way; as the effect of the actual translation, along with the solar system, is masked by relativity.

(3) A crystal possesses permanent intrinsic electric polarisation, because its polar molecules are orientated: and if this natural orientation is pronounced, the polarisation must be nearly complete, so that if the crystal were of the size of the earth it would produce an enormous electric field. But, great or small, this field will become annulled by masking electric charge as above. The explanation of pyro-electric phenomena by Lord Kelvin was that change of temperature alters the polarisation, while the masking charge has not had

opportunity to adapt itself: and piezo-electric phenomena might have been anticipated on the same lines. Thus, as there is not complete compensation magnetically, an electrically neutralised crystalline body moving with high speed of rotation through the æther would be expected to produce a magnetic field: and a planet whose materials have crystallised out in some rough relation to the direction of gravity, or of its rotation, would possess a magnetic field. But relativity forbids that a crystalline body translated without rotation at astronomical speeds should exhibit any magnetic field relative to the moving system.

The very extraordinary feature of the earth's magnetic field is its great and rapid changes, comparable with its whole amount. Yet the almost absolute fixity of length of the astronomical day shows extreme stability of the earth as regards its material structure. This consideration would seem to exclude entirely theories of terrestrial magnetism of the type of (2) and (3). But the type (1), which appears to be reasonable for the case of the sun, would account for magnetic change, sudden or gradual, on the earth merely by change of internal conducting channels: though, on the other hand, it would require fluidity and residual circulation in deepseated regions. In any case, in a celestial body residual circulation would be extremely permanent, as the large size would make effects of ordinary viscosity nearly negligible.

During the meeting, Models of Crystals, devised by Miss Nina Hosali, *were shown, as to which the following statement was issued:—*

The object of these models is

(1) To illustrate the forms possible to crystals;

(2) To show as clearly as possible the different kinds of symmetry possessed by these forms; and

(3) To show how the forms are referred to crystallographic axes.

Each model illustrates one of the thirty-two classes of symmetry, and represents several crystal forms correctly orientated with regard to the crystallographic axes, the latter being shown by black threads. A model consists in the first place of a glass envelope whose shape is that of some simple crystal form, and within this envelope two or three other forms are represented by means of coloured silk threads stretched over frameworks of thin copper wire. By this means it is easy to make the forms intersect if necessary, and they are readily distinguished from one another by the use of differently coloured threads.

The symmetry elements of the class represented by any model are shown as follows:

(*a*) The traces of the *Planes of Symmetry* on the glass envelope are shown by *steel wires.*

(*b*) *Axes of Symmetry* are shown by *white threads.* (If an axis of symmetry and a crystallographic axis are coincident, the white and black threads representing them are twisted together.) The degree of symmetry possessed by an axis is indicated by small numbers attached to the thread near its ends.

(*c*) When simultaneous rotation about an axis and reflection across a perpendicular plane occur to produce *Alternating Symmetry*, the traces of the plane on the glass envelope are shown by *red and white twisted threads*, and the axis is shown by a *white thread*, its degree of symmetry being indicated by small numbers fixed to it and printed in red.

(*d*) When the symmetry elements are such that the forms are *Centro-Symmetrical* (i.e. when the faces occur in parallel pairs), a couple of *white beads* are placed at the centre of the model.

The set of twenty-four models here exhibited represents twenty-one out of the thirty-two classes and over seventy different forms. In many cases different varieties of the forms may be produced by rotating or inverting the models, or by reflecting them in a mirror, and, when these modifications are taken account of, the number of forms shown is brought up to about 140.

SECTION B: CHEMISTRY.

PRESIDENT OF THE SECTION: Professor P. PHILLIPS BEDSON, D.Sc.

TUESDAY, SEPTEMBER 9.

The President delivered the following Address :—

IN again taking up the work of this Section, after an interval of three years, a discontinuity without parallel in the annals of the Association, it is natural that our thoughts should turn to the past, and in so doing we are reminded of the gaps in the ranks of those who were accustomed to contribute to the work of our Section. In 1916 we met under a shadow caused by the death of Sir W. Ramsay, whose genius has added in so many ways to our science. And to-day we have to record the loss of one who in his long life contributed in a variety of ways to the advancement of chemistry, and to whom we owe an addition to the number of elementary substances in the discovery of thallium, one of the early fruits of the use of the spectroscope. The chemistry of the rare earths has been especially illumined by the researches of Sir William Crookes. With physicists we would join in a tribute to the memory of Lord Rayleigh, amongst whose experimental researches is one of special interest to chemists—namely, the revelation of the existence of argon, of which discovery Sir J. J. Thomson has recently written that it was not made 'by a happy accident, or by the application of new and more powerful methods than those at the disposal of his predecessors, but by that of the oldest of chemical methods—the use of the balance.'

In this connection it is but right that, despite the feelings engendered by the war, I should refer to the passing of two great chemists—Baeyer and Fischer. The former died some two years ago, and the latter within the past few months. Each of them has advanced by his experimental researches the progress of organic chemistry, and has brought illumination into many of the obscure departments of this branch of science. The field of investigation latterly cultivated by Fischer has revived an interest in the 'vital' side of organic chemistry as distinguished from the study of the chemistry of the carbon compounds. Moreover, there are many British chemists, amongst them some of the most distinguished, who, as students, received guidance and inspiration from the teaching of Baeyer or of Fischer, and with them we gratefully acknowledge our indebtedness.

Fifty years ago Mendeléeff communicated to the Russian Chemical Society a memoir which has exercised a profound influence on chemical philosophy, and continues to serve as a guide in the interpretation of research and speculations on the nature of the elements. Without entering on the somewhat vexed question as to whom should be assigned the credit of the discovery of the Periodic Law, I trust I shall not be considered unmindful of the claims of Newlands, by adopting the traditional history, and, as is usual, associate this discovery with the name of Mendeléeff, and consequently we may look on this year as the Jubilee of the Periodic Law. Although there is already abundant special literature dealing with this subject, and the periodic system has been assimilated into the teaching of the science and is dealt with in the text-books of chemistry, in some of which it forms the basis of the system employed in the exposition of the

facts and theories of inorganic chemistry, still it appeared to me that I might utilise this as an opportunity of passing in brief review some of the features of the rise and development of the 'Periodic Law.'

The memoir, made known to the non-Russian reader by the abstract in German, shows the principle of periodicity—viz., the recurrence of similar properties at regular intervals with increase in the magnitude of atomic weights, the possibility of utilising the atomic weights as a basis of the classification of the elements, the necessity for the revision of the values thus assigned to the atomic weights of certain elements, and finally that the scheme demanded for its completeness the existence of many new elements.

The later writings of Mendeléeff contain the mode of tabulating the elements in the form usually adopted in chemical text-books, portraying the principle of periodicity and showing the grouping of the elements into natural families. But undoubtedly the clearest demonstration of the association between the atomic weights and the physical properties of the elements is that exhibited by the curve of atomic weights and atomic volumes, which is an outcome of the independent studies of these relationships by Lothar Meyer, and, as is well known, shows the members of the natural families of elements occupying corresponding positions on the curve. This curve, with its undulations, corresponding to the series of the elements, has contributed to impress on the mind of the student the relationship between the properties of the elements and their atomic weights, and may have exercised an influence in drawing attention to these relationships which the attempts of the earlier workers in this field were not successful in doing.

Mendeléeff's Table of the Elements was just beginning to figure in the teaching of chemistry in my undergraduate days, and, together with the speculations underlying it, aroused considerable interest and proved an incentive and inspiration for experimental inquiry. Foremost in this country amongst those who by their writings have contributed to spread a knowledge of Mendeléeff's speculations was my fellow-student, Carnelley. His experimental investigations added materially to our knowledge and definition of the physical properties of elements and compounds, which further emphasised the periodicity in the relation of the atomic weights to the properties of the elements, and have provided data from which curves, resembling in contour the atomic volume curve, have been set up.

A valuable guide in fixing the atomic weights of the elements has been the specific heat which, as the discovery of Dulong and Petit showed a hundred years ago, varies in the case of solid elementary bodies inversely with their atomic weights; or, as is more usually expressed, the solid elements have the same atomic heat. The investigation of the exceptions to this empirical rule brought out the fact that the specific heat is influenced by temperature, and the study of the influence of low temperatures led Sir James Dewar to the discovery that at about 50° Absolute the atomic heats of the elements are a periodic function of the atomic weights. Further, the graphic representation of this relation gives a curve very similar in its course to that of the atomic volume curve. So that the specific heat is another of the physical properties to fit into the periodic scheme.

The necessity for a revision of the atomic weights of certain elements, as pointed out by Mendeléeff, has induced several workers to direct their energies to the solution of the problems indicated, so that in our present-day tables many of the anomalies of position and sequence which existed in the earlier schemes have disappeared. Tellurium has still resisted all attempts to bring it into order, with an atomic weight less than that of iodine, which its association with sulphur and selenium demands. The interesting attempts to decompound tellurium have so far remained unfruitful.

But undoubtedly the most fascinating feature of the periodic system is that 'it allows the discovery of many new elements to be foreseen.' This and the manner in which Mendeléeff, in full conviction of the truth of the 'Periodic Law,' boldly assigned properties to those elements required to fill the blank spaces in the table of elements, and the verification within twenty years in three instances of these prophetic specifications have contributed to the recognition and firm establishment of the 'Periodic Law' as an article of belief in

chemical philosophy, and to make it the mainspring and inspiration of the greater part of modern inorganic research.

The discovery of argon, the announcement of which formed a notable feature in the proceedings of the Association at the Oxford meeting in 1894, and the recognition in it of an element with an atomic weight of 40, raised doubts in the minds of some as to the validity of the scheme of the elements based upon the Periodic Law. It was indeed a time of testing the faith. The suggestion that argon would prove to be a modified form of nitrogen was brushed aside by the incontrovertible establishment of it as an element, endowed only with specific physical properties and distinguished from all known elements by its lack of any of those activities which characterise the remaining elements. But argon was not destined to enjoy a splendid isolation for long. The researches of Sir W. Ramsay soon brought helium to earth, and he and his colleagues provided a number of companions for argon. So, in a very short period, was recognised the existence of a group of gaseous elements forming a natural family, whose molecules are monatomic, the members of which are distinguishable by their spectra and atomic weights, but are all in agreement in their unreadiness to take part in any chemical change. This inertness or nonvalence provided a simple means of reconciliation with the periodic scheme of the elements, as all that was required was simply to add to the eight groups of the table of elements a zero group containing helium, neon, argon, krypton, and xenon, and with niton, the emanation from radium, as a recent addition. If we are to accept Mendeléeff's suggestion, the zero group should contain a member lighter than hydrogen, in Series I., and in a zero series a still lighter representative of the elements of the zero group, which he has postulated as the 'ether' of the physicist.

Thus the discovery of argon has formed a starting point in the development and a justification of the natural system of the elements, but it still remains, to make the tabulation complete, that provision should be made for the accommodation of the rare earths. The paper published by Werner in 1905, under the title 'A Contribution to the Development of the Periodic System,' shows how this can be satisfactorily accomplished.

The elements of the argon group form a valuable extension to the periodic system, and the knowledge acquired in the investigation of these substances has proved serviceable in the solution of problems in the realms of science and of industry. The knowledge of the properties and behaviour of helium was destined soon to play a part in the solution of the riddle of the radio-active elements, whilst it is specially noteworthy that argon, the 'idle one,' should have been pressed into industrial service.

This fact suggests the thought that idleness has its uses, and at the present time how satisfactory would it be were we able to find useful application for a quality which appears to be plentifully and widely distributed in this country.

The history of helium is still more astonishing, for not until thirty years after its existence had been surmised from spectroscopic observations of the sun was this element found to have a terrestrial existence, and now, as one of the achievements of science during the war, we may look on its production in bulk as a commercial proposition. Moreover, we are told 'that the advances made in the production of helium warrant the opinion that, had the war continued after November 11, 1918, supplies of helium at the rate of 2,000,000 cubic feet per month would have been produced within the Empire and the United States, and helium-filled aircraft would have been in service.' [1]

Some of the speculations that the periodic system of the elements has given rise to have been the subjects of communications to this Section.

At the Aberdeen meeting Carnelley, whom I have already mentioned as an ardent worker in this field, gave an account of a scheme based on the conception that the elements are composite, having relations similar to those exhibited by the paraffin hydrocarbons and the isologous series of radicals derived from them. He regarded the elements, other than hydrogen, as made up of two simple elements, A and B. A he identified with carbon, with the atomic weight of 12, and B was assumed to have a negative atomic weight of 2.

[1] *Nature*, July 17, 1919.

In the following year, at Birmingham, Sir W. Crookes devoted his address to this Section to an exposition of his ideas of the 'Genesis of the Elements,' a subject to which he on many subsequent occasions returned, and amplified in the light of recent discovery. The process of evolution of the elements from a primal 'protyle' is depicted as taking place in cycle after cycle, in each cycle the 'unknown formative cause' scattering along its journey clusters of particles corresponding to the atoms of the 'elements,' forming in this way a series such as that beginning with hydrogen and ending with chlorine; a repetition of the movement under somewhat altered conditions giving rise to a series of similarly related elements, and thus homology, which is shown by the members of the natural families, is provided for.

The investigations of Sir J. J. Thomson on the discharge of electricity through gases have established the divisibility of the atoms, and in his 'Corpuscular Theory of Matter' he has given us conceptions of how atoms may be constituted to provide a series so related that they reflect, if not reproduce, many of the chemical characters of the elements and their periodic relation to atomic weights.

With the discovery of radium and its remarkable properties we have been brought in contact with an element undreamt of in our philosophy. The interpretation of the results of the investigation of this element has called for drastic changes in our conception of an element. The pursuit of the researches of the radio-active elements, guided by the theory of the spontaneously disintegrating atom propounded by Rutherford and Soddy, has served to reveal facts which lend a special emphasis to many passages in the address of Sir W. Crookes to which I have already referred.

For instance, the passage in which he said: 'Should it not sometimes strike us, chemists of the present day, that after all we are in a position unpleasantly akin to that of our forerunners, the alchemists of the Middle Ages? The necromancers of a time long past did not, indeed, draw so sharp a line as do we between bodies simple and compound; yet their life-task was devoted to the formation of new combinations, and to the attempt to transmute bodies which we commonly consider as simple and ultimate—that is, the metals. In the department of synthesis they achieved very considerable successes; in the transmutation of metals their failure is a matter of history.'

Or again, when he propounded the question, 'Is there, then, in the first place, any direct evidence of the transmutation of any supposed "element" of our existing list into another, or of its resolution into anything simpler?'—a question to which he, Sir William Crookes, was at that time forced to reply in the negative, whereas to-day many instances might be cited in support of an affirmative answer to this question. Radio-activity has supplied a method of analysis—radio-active analysis—surpassing in delicacy any of the previously known methods for the examination of material substance; the application of these methods has not only added to the list of elements but also new classes of elements. First, elements indistinguishable and inseparable by chemical means, yet differing slightly but definitely in their atomic weights. The existence of these 'isotopes,' as Soddy styles them (a name giving prominence to the fact that such elements occupy the same place in the table of the elements), demonstrates that absolute uniformity in the mass of every ultimate atom of the same chemical element is not an essential, but that 'our atomic weights merely represent a mean value around which the actual atomic weights of the atoms vary within certain narrow limits.'[2]

Whether the possibility of separating isotopes, recently suggested by Dr. Lindemann and Dr. Chapman, will be found capable of experimental realisation, must be left to the future to decide; in fact, in this matter we must adopt the attitude, prevalent in other than scientific circles, of 'wait and see.'

The investigations in the field of radio-activity have further brought to light that identity in atomic weight may be associated with difference in chemical properties, revealing the existence of a further class of elements for which Dr. Stewart suggests the name 'isobares.' Further, Dr. Stewart considers that

[2] Crookes. Address to Section B. 1886.

isobaric elements are to be found not alone amongst the radio-active, but some of the normal elements exhibit properties which may be explained on the assumption that they are isobarics. Thus the compounds formed from iron are regarded as indicating the existence of three irons, all having the same atomic weight. One of these, termed ferricum, is tervalent; one, ferrosum, is divalent; whilst the third, ferron, is inert and takes no part in chemical changes. The three are under certain conditions mutually interconvertible. This last condition does not apply in the case of the radio-active isobares.

The elements are to be regarded as divisible into three classes: (1) Isotopic elements, each set of which have different atomic weights but identical chemical properties; (2) Isobaric elements which have identical atomic weights but different chemical properties; (3) Normal elements which differ from each other both in atomic weights and chemical properties.

The discovery of X-rays may be acclaimed as having added a new sense to aid us in our investigation of material objects, and to their innumerable services may be reckoned the results which have followed from the investigations of the X-ray spectra of the elements by the late Lieut. Moseley, whose death in Gallipoli in 1915 is one of the many tragedies of the war specially deplored in the scientific world. From the analysis of the X-ray spectra, Moseley has shown that for each element a value can be deduced, which is styled the atomic number and which represents the space in the atomic table the element should occupy. The researches of Rutherford and Andrade on Lead and Radium B have proved that 'isotopes' have the same atomic number. Whatever may be the ultimate explanation of the meaning of the atomic numbers, their experimental determination has already proved valuable in the solution of some of the anomalies of the Periodic Table. In addition to the case of isotopes, just referred to, the number of elements between hydrogen and uranium is fixed by finding 92 as the atomic number for uranium, and further, Moseley's work has revealed that the atomic numbers are in agreement with the order of the chemical sequence, rather than the order of the atomic weights, which is of special interest and value in the cases of tellurium and iodine, and of potassium and argon, the decision in each case proving a welcome support to the position in the table assigned to these elements on chemical considerations.

Again, Moseley's atomic numbers remind us of the arrangement of the elements adopted by Newlands in his communication to the Chemical Society of 1866, in which he set forth the 'Law of Octaves,' the precursor of the Periodic Law.

In concluding this brief sketch, cognisance should be taken of the speculations of physicists as to the structure of the atom. Already several models of the atom are in the field which leave the uncuttable Daltonian atom far out of view, still in a measure they help to an understanding of some of those regularities exhibited by the elements, and set forth in the natural system. Valency and its vagaries, which we are accustomed to describe by phrases, such as 'variable valency,' 'selective valency,' and the like, still call for a full explanation.

I purpose now to direct attention to matters of another nature, which appear to me of interest to chemists, and to that extent have a bearing on the welfare of chemistry in this country.

Among the numerous revelations and surprises of the past five years has been the realisation on the part of the public and the Government of the importance of the chemical industries to the national well-being. The apathy and indifference of pre-war times were replaced by an apparently lively interest in things chemical, and there was what in the religious world would be styled a revival.

Politicians, the Press in all its varied forms, daily, weekly, monthly, and quarterly, took up the subject of our industrial insufficiencies and emphasised in various ways the importance of research in connection with our industries. Again, the coal-tar colour industry furnished, as it had done again and again, some thirty to forty years ago, the text from which research and its importance was preached. This time the reiteration had the effect that the 'aniline phantasm,' as I have seen it described, was recognised as a 'key industry,' important to the vitality of the manufacture of textiles; with the result that the Government, discarding its fiscal policy, was induced to subsidise the

enterprise for the manufacture of dyes and other coal-tar products. The negotiations preceding the formation of the 'British Dyes Co., Ltd.,' have been remarkable as revealing that in the eyes of some, at any rate, special knowledge is a 'dangerous thing,' and, in fact, was deemed sufficient to exclude its possessors from a seat on the directorate. This is all the more remarkable as the history of similar enterprises in Germany shows the *personnel* of the directorates to be made up of university-trained men and, in not a few instances, of professors. So that in Germany academic distinction and theoretic learning are not considered as excluding the possession of commercial acumen and those other qualities needed in a successful man of business.

In the early stages of the war the demand for explosives was met by the expansion of already existing factories, the increase in staff of which called for many additional men with chemical training, a call which became unprecedented and insistent when the national factories were founded, so that men and women with a chemical training found an opportunity of putting their knowledge at the service of their country. And in not a few instances those who, for financial reasons, had at the close of their college career taken up a less congenial employment were able to return to the practice of chemistry, for which in their student days they had specially fitted themselves.

In the foreword of the publication 'Reports on Costs and Efficiencies for H.M. Factories,' issued by the Ministry of Munitions, we are told 'when it was decided to commence the erection of new and national factories, and an attempt was made to collect from existing factories the necessary technical data and assistance, did it become evident that, due to the extraordinary demands of the war, there was—practically throughout the entire country—a regrettable lack of available accurate technical data, and an even greater lack of trained technical men—more particularly chemical engineers.'

To anyone acquainted with the conditions existing in this country in pre-war days, the lack of 'trained technical men' is no matter of surprise. In fact, one cannot fail to be astonished at the phenomenal development of chemical manufacture which has taken place under the directing influence of Lord Moulton, in response to the call from Army to Navy. That men were found capable of taking a part in these varied undertakings, cannot, at any rate, be credited to the encouragement which the teaching of chemistry or the students of the science had received from those directing industries which employ or should employ the services of chemists. It is no uncommon experience to find the chemist employed simply in the analytical testing of raw materials and manufactured products, and even in the working of processes under their control the potentiality of the chemist is not utilised to the full, as is evident from the following, which is a quotation from the Preface to the brochure, issued by the Ministry of Munitions, to which I have already referred : 'Since the beginning the policy of the Department with regard to our national factories has been to aim at maximum efficiency in respect of cost and usage of materials.

'For this purpose the greatest efforts have been made to place before all those who are in any way responsible for control full details concerning the working and costs of the factories. This was rather an innovation in the field of chemical manufacture, as until comparatively recently, either intentionally or through negligence, it was customary at many chemical plants to keep the chemists in complete ignorance not only of the cost at their plants but also even of the efficiencies.

'It is amazing that manufacturers can expect improvements in chemical processes when their chemists are kept in ignorance of such vital facts.

'It has happened very often that as soon as detailed figures were seen by chemists at a plant, important alterations and improvements have at once been suggested, the need for which would otherwise never have been noticed.'

The condition of service indicated in the passage quoted, together with the low scale of remuneration which obtained hitherto in chemical industries, help to explain the scarcity of the kind of scientific labour referred to in the quotation I have made from the 'Foreword.'

But are we not told and invited to believe that all this is changed, that the records of the magnificent achievements of British chemists in the war have so educated the people and, may we say, the Government also, that the prac-

titioners in chemistry will no longer find it essential that in describing their vocation they should be required to add, unless for special reasons, such prefixes as 'analytical,' 'research,' 'scientific,' or 'engineering' to the word chemist, secure in the feeling that by describing themselves as 'chemists' their standing, training, and profession will be correctly understood.

Still a feeling akin to despondency, if nothing worse, is pardonable, when realising the fundamental importance of chemistry to our industries, and the thousand and one ways chemical research has ministered to the amenities of our every-day life, there should exist not alone in the mind of the general public, but of the educated also, such a lack of information as has been revealed during the past few years—to wit, the myth woven into the history of the production of glycerine, the confusion in the minds of legislators between phosphates and phosgene. More serious, however, is the fact that the method of investigation employed by the chemist is so little appreciated or understood as to lead one to imagine that the discoveries and achievements are the results of a species of legerdemain. The production of new colours, a succession of happy thoughts, and that 'by an accident the secret of synthetic indigo was unlocked.' This last is a quotation from a review entitled 'The Value of Scientific Research,' published some three years ago, and is typical of much that passes muster in appraising the value of chemical research. That the unravelling of the constitution of indigo which occupied Baeyer and his pupils some thirteen years, the account of these investigations covers some 180 pages of Baeyer's collected works, should be summarised in this way appeared to me to call for a protest. My protest was made and I attempted to put the matter in the correct light, showing the synthesis of indigo to be, indeed, a brilliant example of the value of theory and of a practical illustration of the importance of the chemist's conception of the Architecture of Molecules, as exemplified by Kekulé's theory of the constitution of benzene. The protestation evoked a reply from a correspondent, signing himself D.Sc., Ph.D., who sought to justify the description of the revelation of the secret of synthetic indigo by reference to an accident which occurred in the investigation of the processes for the manufacture of phthalic acid and which certainly greatly facilitated the production of this substance, an intermediate in the manufacture of artificial indigo. So, if the initiated emphasise the unessential, why should we blame the layman and be surprised that well-ordered and planned design should appear to be but the workings of chance, for every such achievement is a witness to the conquest of well-founded theoretical speculation?

But I do not wish to conclude on a despondent note, nor is it right that I should do so, in view of the many activities operating for the promotion of scientific research, and of such evidence as that supplied by the magnificent endowment of the Chemical Department of the University of Cambridge, all of which are evidences of what we may reasonably hope to be a happy augury for the future of chemistry and chemists in this country.

The following Papers were then read :—

1. *Chemistry and the War.* *By* Sir William J. Pope, *F.R.S.*

2. *Chemical Warfare.* *By* Brigadier-Gen. H. Hartley. (See p. 393.)

3. *High Explosives.* *By* Lieut.-Col. C. D. Crozier.[1]

[1] See *Journ. Royal Artillery*, vol. 46, No. 9.

WEDNESDAY, SEPTEMBER 10.

The following Papers were read :—

1. *Metallurgy during the War.* *By* Professor C. H. Desch, *D.Sc.*

2. *Glass Manufacture at the end of the War.* *By* Dr. M. W. Travers.

3. *The Recovery of Nitre and Pitch from Smoke Candles.* *By* Major E. R. Thomas.

4. *Geochemistry and the War.* *By* Professor P. G. H. Boswell.

5. *Equilibrium in the System* $NaNO_3$—NH_4Cl—$NaCl$—NH_4NO_3. *By* Dr. T. M. Lowry, *F.R.S.*, *and* Dr. E. P. Perman.

THURSDAY, SEPTEMBER 11.

The following Papers were read :—

1. *Industrial Bacteriology.* *By* Dr. C. A. Thaysen.[1]

2. *The Mechanism of the ' n-Butyl Alcohol and Acetone ' Fermentation Process.*

By Joseph Reilly, *M.A.*, *D.Sc.*, *and* Wilfred J. Hickinbottom.

Among the more recent applications of bacteriology to technical processes is the conversion of carbohydrates into a mixture of *n*-butyl alcohol and acetone (A. Fernbach and E. Strange, E. P. 21073, 1913). Certain bacteria are known, as, for example, *granulobacter butylicum*, *bacillus amylobacter*, and the butylic bacillus of Fitz, *tyrothrix tenuis*, which, under certain conditions, convert carbohydrates mainly into *n*-butyl alcohol and acetone, producing, in addition, carbon dioxide and hydrogen, together with small quantities of acids and other alcohols (chiefly ethyl). From 100 grams of maize may be produced 7 grams of acetone, 16 grams of *n*-butyl alcohol, 2 grams of volatile fatty acids, 19 litres of carbon dioxide, and 16 litres of hydrogen at 20°.

In a normal fermentation, which usually lasts about 24-30 hours, the acidity of the mash gradually increases from a very small value until 10 c.c. of the mash liquor requires from 3.5 to 4.5 c.c. of 0.1 *N*-sodium hydroxide solution for neutralisation, after eliminating carbon dioxide. Usually 13 to 17 hours are required before the acidity reaches its maximum value, when the formation of acetone and *n*-butyl alcohol commences. The actual value for the maximum acidity and the interval before the *n*-butyl alcohol and acetone are formed, depends to some extent on the experimental conditions, the source of carbohydrate, and the percentage of inoculant. During the production of acetone and *n*-butyl alcohol in the mash, the acidity falls gradually to a constant value of about 1.5-2.5 c.c. of 0.1 *N*-sodium hydroxide per 10 c.c. of mash. It was considered that, in view of these variations, a study of the acid-formation in the fermenting mash might give an insight into the fermentation process.

The acids present in the mash are principally acetic and butyric acids with a small quantity of a non-volatile acid. It is found that the ratio of these acids to each other depends on the age of the fermentation. Shortly after inoculating, the acids are present in the proportions of approximately 4 or 5 molecules of acetic acid to one of butyric acid, but as the acidity increases, the ratio of acetic acid to butyric falls, until at the period of maximum acidity there are about 1.1 to 1.4 molecular proportions of butyric acid to one of

[1] To be published in *Journ. Inst. of Brewing.*

acetic acid. During the production of the acetone and alcohol the ratio of acetic to butyric acid increases gradually, so that, when the fermentation is completed, the volatile acids in the mash are 4 or 5 parts of acetic and one part of butyric acid.

The fluctuations in the relative amounts of the two acids present in the mash would indicate that the acids are intimately connected with the production of acetone and *n*-butyl alcohol, especially as the formation of the latter substances may be suppressed almost completely by conducting a fermentation in presence of calcium carbonate. Under these conditions the main products formed are acetic and butyric acids. These acids are obtained in the ratio of ten molecules of acetic to nine molecules of butyric. Using these proportions, and assuming that *n*-butyl alcohol and acetone are formed from the acids without any appreciable side reactions, *n*-butyl alcohol and acetone should be produced in the ratio of 2·3 parts by weight of the former to one of the latter. Such a result is in accordance with the actual yields obtained. It seems likely, therefore, that the *n*-butyl alcohol is produced from the butyric acid. In support of such a view, several facts are adduced; the decrease of the amount of butyric acid in the mash is coincident with the formation of *n*-butyl alcohol; the hypothesis is in agreement with experimental data given by Buchner and Meisenheimer (Ber., 1908, **41**, 1410); the reduction of butyric acid to butyraldehyde has been observed to be brought about by certain extracts; the addition of butyric and propionic acids results in the formation of *n*-butyl and *n*-propyl alcohols respectively; *n*-butyric acid has been observed in most fermentations in which *n*-butyl alcohol is obtained.

It is also probable that the acetic acid is an intermediate substance in the formation of the acetone, since the decrease in the amount of this acid in the mash during the fermentation is much slower than that of butyric acid. The amount of acetone produced is only half that of the alcohol. Also on adding acetic acid to the fermenting mash it is found that the added acid is converted principally into acetone. The fatty acid is best added periodically some hours after the maximum acidity of the mash has been reached, in such a manner as to maintain a figure for the acidity of the mash equal to the maximum acidity obtained in a normal fermentation.

There is produced also in the fermentation a small amount of ethyl alcohol. It is not yet determined whether this is obtained in a side reaction, or whether it is due to the presence of some impurity.

The two volatile fatty acids in the mash appear to be attacked, each in a different manner, the butyric acid undergoing a reducing action, while the acetic acid is condensed to acetone. To account for this difference it is suggested that the formation of dipropyl ketone by condensation from the butyric acid may be prevented owing to the increased steric hindrance imposed by the presence of large groups.

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3. *Intramolecular Rearrangement of the Alkylarylamines.*

By Joseph Reilly, *M.A., D.Sc., and* Wilfred J. Hickinbottom.

The intramolecular change brought about by heating the hydrochlorides of the alkylanilines under pressure is well known (Hofmann, Ber., 1872, **5**, 720). It is now shown that not only the hydrochloride but also certain addition compounds of the secondary and tertiary amines with metallic salts are capable of undergoing this change on heating. Compounds of the type $B.RCl_2$ (where B represents one molecule of a monovalent base, and R one atom of a divalent metal), produced by the addition of chlorides of zinc, cobalt, and cadmium, to the secondary amines, readily yield alkyl nuclear substituted amines, on heating under pressure. Unless the assumption is made that these double compounds readily split off hydrogen chloride, it is difficult to reconcile these facts with the view that methyl chloride is an intermediate product in the formation of *p*-toluidine from methylaniline double salts.

In the alkylarylamines each group occupies a definite space and has a certain definite vibration path. If a change of conditions occurs each group will tend to occupy a position in which the vibration is least restricted. This may occur simply on heating, or by combination or reaction with another compound.

In the case of heating alone only a slight effect is apparent, but in presence of a substance which can cause an alteration in the arrangement of the molecule some profound change occurs. The extent of the rearrangement and consequently the ease with which the change occurs, will depend on several factors, among which the steric effect of constituent groups and the free valency have an important influence.

It might be expected that, in the series of alkylanilines, the larger groups would show a tendency to be removed before the smaller ones. Comparative experiments with monoalkylanilines indicate that the total amount of change including intramolecular rearrangement, brought about on heating in sealed tubes, does not differ greatly whether the alkyl group is butyl or methyl. It is suggested that the other influences, such as the increasing steric hindrance imposed by the larger alkyl groups, may modify the reaction.

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4. *Distillation of Aqueous Solutions of Related Organic Substances.* *By* Joseph Reilly, *M.A., D.Sc., and* Wilfred J. Hickinbottom.

When dilute solutions of organic fatty acids are distilled, it is well known that certain regularities are observed (compare Duclaux, Ann. Inst. Pasteur, 1895, **9**, 265, 575; Naumann and Müller, Ber., 1901, **34**, 224; Stein, J. pr. Chem., 1913, **88**, 83). Various forms of distillation constants have been advanced by these authors to express such regularities. These constants may be derived from Nernst's law of distribution. This law may be used as a starting-point for the discussion of the theory of distillation of dilute solutions (Reilly and Hickinbottom, Sci. Proc. Roy. Dub. Soc., 1919, **15**, 513). For large changes in concentration Nernst's law does not hold exactly, and a method of steam distillation is recommended in which only small changes in concentration occur. By plotting the constants for the normal fatty acids (formic to caprylic acid) against the number of carbon atoms present in the acid, an approximately straight line results, showing an interdependence between molecular constitution and rate of steam distillation. Acids containing a branched carbon chain (as isovaleric) have greater constants than normal acids of the same molecular weight. The experimental evidence at present available shows that for isomeric substances (as for example *normal* and *iso* butyric acids), the distillation constants are distinct enough to differentiate between the substances.

The lower saturated monohydric alcohols, phenols, and other substances have been distilled in a current of steam under definite conditions, and results have been obtained showing a relation between molecular complexity and the distillation constants.

In cases where the constitution of a substance is uncertain, and when it is volatile in steam, a comparison of its distillation constants with those of allied substances may assist in deciding its molecular constitution.

Within certain limits the distillation constants for formic and acetic acids and the lower saturated aliphatic alcohols are subject to variations depending on the concentration. The addition of certain non-volatile substances, such as acids or salts, also causes an alteration in the distillation constants. As the homologous series of saturated fatty acids and alcohols are ascended, the distillation constants increase with the molecular weights, the reverse of what might be expected from a knowledge of the vapour tension of the pure substances. It is considered likely that the tendency for the acids or alcohols to form molecular complexes may account for this behaviour.

As well as using the method of steam distillation for analysis of fermentation products, and various technical preparations containing the volatile fatty acids, a method has been worked out to detect the presence of butter and of fats of the coconut-oil type in margarine and other products. By determining the distillation constants of the water-soluble volatile acids under definite conditions, constants for the fats are obtained which differ considerably in the case of butter fats compared with other fats which have been examined (coconut oil, palm-kernel oil, babassu fat).

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5. *Addition Compounds of Aromatic Amines and their Nitro-derivatives with Metallic Salts.* *By* JOSEPH REILLY, *M.A., D.Sc., F.R.C.Sc.I.*

Certain *p*-nitroso derivatives obtained during a study of the butylarylamines were characterised by the formation of addition products with various metallic salts (Reilly and Hickinbottom, Trans. Chem. Soc., 1918, **113**, 105, 928). *p*-Nitrosodibutylaniline yielded double salts with the chlorides of zinc, cadmium, copper (cupric), mercury (mercuric), iron (ferric), manganese (ous), tin (stannic), and with the nitrates of nickel, cobalt, and copper. 5-nitroso-*n*-butyl-*o*-toluidine also gave a double salt with cupric chloride.

It has been observed that secondary and tertiary amines, such as mono- and di-butylanilines, are able to combine with metallic salts.

Derivatives of methylaniline and butylaniline with cobaltous chloride, zinc chloride, and cadmium chloride were prepared and compared.

Although the derivatives of the alkylanilines with metallic salts must be considered as formed by the calling into play of the residual valency of the nitrogen, the double salts with *p*-nitrosoalkylanilines may either be considered as nitrogen or as oxygen addition substances. Pickard and Kenyon (Trans. Chem. Soc., 1907, **91**, 896) showed that nitrosobenzene also combine additively with metallic salts. The colour of the *p*-nitrosodimethylaniline zinci-chloride differed also from that of salts which are considered to be true nitrogen addition compounds. They suggested that these compounds of *p*-nitroso-alkylanilines were due to the residual valency of the oxygen atom.

The comparative ease with which the different mono-substituted anilines yield addition compounds has been studied. It is found that aminophenols form a double complex more readily than nitroanilines. Also the stability of the addition compounds of the alkylarylamines is less than that of the corresponding metallic salt derivatives of the primary arylamines. In general, by altering the basicity of the amino group, or by causing an alteration in the disposal of the valencies of the nitrogen atom, the power to yield additive products is altered.

Taking into consideration the behaviour of nitroso-hydroxy compounds, and the ability of nitrosobenzene to yield addition compounds, it is possible in *p*-nitrosoalkylarylamines that not only the amino group but also the nitroso group may have an influence on the formation of a complex with a metallic salt.

In the afternoon a sectional excursion took place to H.M. Naval Cordite Factory, Holton Heath, by kind permission of Capt. DESBOROUGH.

FRIDAY, SEPTEMBER 12.

1. *Discussion of Report on Fuel Economy.*
(For Report see p. 97.)

The following Papers were then read :—

2. *An Automatic Filter for measuring the suspended Dust in the Air.* *By* Dr. J. S. OWENS.

3. *The Molecular Phase Hypothesis: a Theory of Chemical Reactivity.* *By* Professor E. C. C. BALY, *C.B.E., F.R.S.*

4. *Latent Polarities in the Molecule and Mechanism of Reaction.* *By* Professor A. LAPWORTH, *F.R.S.*

5. *The Conjugation of Negative and Positive Valencies.* *By* Professor R. ROBINSON.

Section C.—GEOLOGY.

President of the Section: J. W. Evans, D.Sc., LL.B., F.R.S.

TUESDAY, SEPTEMBER 9.

The President delivered the following Address:—

I propose in this address to consider the methods by which the progress of geological research may be most effectively promoted, and to point out some directions in which I think it possible important advances may be made in the early future.

One of the most striking features of our science is the need in which it stands of a large and widely distributed body of workers, and the opportunities it affords to every one of them of making important contributions to scientific knowledge.

Every locality has its geological history stretching away into the 'dark backward and abysm of time,' and this history has left its records in the rocks of the earth's crust: an imperfect record, it is true, for much of it has long since been destroyed, but enough remains to reward long years of patient labour in deciphering it.

Everywhere someone is needed who will devote his spare time to the examination of the quarries and cliffs, where the materials that build up the solid earth are exposed to view, and who will record the changes that occur in them from time to time; for a quarry that is in work, or a cliff that is being undermined by the sea, constantly presents new faces, affording new information, which must be recorded if important links in the chain of evidence are not to be lost. It is equally important that some one should always be on the look-out for new exposures, road or railway cuttings, for instance, or excavations for culverts or foundations, which in too many instances are overgrown or covered up without receiving adequate attention. It is, again, only the man on the spot who can obtain even an approximately complete collection of the fossils of each stratum and thus enable us to obtain as full a knowledge as is possible of the life that existed in the far-off days in which it was laid down. In his absence, many of the rarer forms which are of unique importance in tracing out the long story of the development of plants and animals, and even man himself, never reach the hands of the specialist who is capable of interpreting them. It was an amateur geologist, a country solicitor, who saved from the road-mender's hammer the Piltdown skull, that in its main features appears to represent an early human type, from which the present races of man are in all probability descended. Another amateur, who was engaged in the brick-making industry near Peterborough, has provided our museums with their finest collections of Jurassic reptiles. A third, a hard-worked medical man, was the first to reveal the oldest relics of life

that had at that time been recognised in the British Isles; and many more examples could be instanced of the services to geological science by those whose principal life task lay in other directions.

Such workers are unfortunately all too few—fewer, I fancy, now than they were before the pursuit of sport, and especially of golf, had taken such a hold upon the middle classes and occupied so considerable a portion of their leisure hours and thoughts. One might hope that the extended hours now assured to the working classes for recreation would lead to a general increase of interest in science among them, if it were not that the students of that admirable organisation, the Workers' Educational Association, seem almost invariably to prefer economic or political subjects to the study of Nature, a choice in defence of which they could no doubt advance most cogent arguments. In a large county in which I am interested the number of those in every condition of life who are able and willing to take part in geological research might be told almost on the fingers of one hand, and so far as I am aware there has not been a single recruit in recent years from the ranks of the younger men or women.

It seems strange that there are so few of our fellow-countrymen or country-women who feel a call to scientific research, especially in a subject which, like geology, makes a strong appeal to the imagination, telling us of the strange vicissitudes through which our world and its inhabitants passed before they assumed the guise and characters with which we are familiar. How few are there who realise that the prolific vegetation to which we owe our wealth of coal was succeeded after the lapse of incalculable years by far-stretching deserts, and these, after continuing for a period still longer in duration, were submerged beneath wide inland semi-tropical seas, under whose waters were accumulated the sediments of sand and mud and calcareous *débris* out of which the fertile valleys of Central England have been carved; or that the conditions under which we now live were only reached through the portals of bleak, desolate ages of excessive cold, the reasons for which we are still at a loss to understand.

Even if the appeal to the imagination were not a sufficient incentive to the cultivation of geology, one would have thought its economic importance would have been effective. Its intimate bearing on the problems of agriculture, engineering, water-supply, and hygiene is too obvious to need emphasis here, and it is scarcely more necessary to point out that all our fundamental manufacturing activities, without exception, are dependent on adequate supplies of materials of mineral origin, so that we need not be surprised that one of the earliest administrative acts of the Imperial Conference was the constitution of an Imperial Mineral Resources Bureau to secure that the whole mineral resources of the Empire should be made available for the successful development of its industries.

It might be suggested that the prevailing indifference to the attraction of geological research was due to a conviction that after eighty years of work by the Geological Survey, as well as by University teachers and amateurs, there was little left to be done, and that all the information that could be desired was to be found in the Survey publications. Such a belief can hardly be very widespread, for, as a matter of fact, comparatively few of the general public realise the value of the work of the Geological Survey, and still fewer make use of its publications. Municipal libraries, other than those of our largest provincial centres, are rarely provided with the official maps and memoirs relating to the surrounding areas, and in the absence of any demand the local booksellers do not stock them. This cannot be attributed to the cost, for, though most of the older maps are hand-coloured and therefore expensive, the later maps—at least those on the smaller scales*—are remarkably cheap, and the memoirs are also issued at low prices.

The true explanation appears to be that a geological map conveys very little information to the average man of fair education who has received no geological instruction. This is certainly not the fault of the Survey maps, which compare very favourably with those of other countries, and have been

* 1 inch to the mile, 1 : 63,360; ¼ inch to the mile, 1 : 253,440; and 1 inch to 25 miles, 1 : 1,584,000.

greatly improved in recent years. In particular, the introduction of a longitudinal section on each map and the substitution of the vertical section drawn to scale for the old colour index must greatly assist those into whose hands it comes in obtaining a correct view of the succession of the strata and the structure of the country. Some of the maps are, it is true, so crowded with information—topographical and geological—that it is frequently difficult, even for the trained geologist, to read them without a lens. This is largely due to the fact that they are printed over the ordinary topographical maps in which there is a great amount of detail that is not required in geological maps. In India the Trigonometrical Survey are always ready to supply, as a basis for special maps, copies of their own maps printed off plates from which a portion of the topographical features have been erased.

The best remedy, however, would be to extend the publication of the maps on a scale of 6 inches to a mile (1 : 10,560). For many years all geological survey work has been, in the first place, carried out on maps of this scale, but they have not been published except in coal-mining areas. There the geological boundaries are printed, but the colouring is added by hand, which makes the maps comparatively expensive. In other localities manuscript copies of the geological lines and colouring on the Ordnance Survey maps can be obtained at the cost of production, which is necessarily considerable.

There is, I believe, a wide sphere of usefulness for cheap colour-printed 6-inch geological maps, especially in the case of agricultural and building land, for which the 6-inch Ordnance maps are already in demand. They afford ample room for geological information, and, accompanied by longitudinal sections on the same scale without vertical exaggeration, their significance would be more readily apprehended than that of maps on a smaller scale. It may be noted that this is the favourite scale employed by those engaged in independent geological research for their field work, and, when the area is not too great, for the publication of their results.

It would be of great advantage if there were a uniform usage by which the position in the stratigraphical series of rock outcrops were indicated by colour and their lithological character by stippling (in black or white or colour) following the ordinarily accepted conventions. This course has been pursued by Professor Watts in the geological map prepared by him to illustrate his 'Geography of Shropshire.' This increases the practical value of the map for many purposes, but is only possible when it is not overburdened with topographical detail.

Some explanation, apart from the maps themselves, is however needed if they are to be rendered, as they should be, intelligible to the general public. The official memoirs which deal with the same areas as the maps do not afford a solution of the difficulty. Excellent as they are from the technical standpoint and full of valuable information, they convey little to the man who has not already a considerable acquaintance with the subject. What is needed is a short explanatory pamphlet for each map, presuming no previous geological knowledge, describing briefly and in simple popular language the meaning of the boundary lines and symbols employed, and the nature and composition of the different sedimentary or igneous rocks disclosed at the surface or known to exist below it in the area comprised in the map. A brief account of the fossils and minerals visible without the aid of a microscope should also be included. The probable mode of formation of the rocks and their relation to one another and the subsequent changes they have undergone should be discussed, and at the same time their influence on the agriculture value of the land and its suitability for building sites, as well as on the distribution and level of underground water, should be pointed out. Some account too should be given of the economic mineral products and their applications.

These pamphlets should be illustrated by simple geological sections, views of local quarries and cliffs showing the relative positions of the different rocks, figures of the commoner fossils at each horizon, and, where they would be useful, drawings of the forms assumed by the minerals. Each pamphlet would be complete in itself. This would involve a considerable amount of repetition, but it must be remembered that different pamphlets would have as a rule different readers. An alternative plan would be to follow the example of the United States Geological Survey and reprint the same brief résumé of geological

principles in every case with such additions as are required to explain the meaning of individual maps. There can, however, I think, be no doubt that an explanation written expressly for each map can be made at once more easy to understand and more interesting to those without special geological knowledge.

That something further is required to render the information contained in the Geological Survey Maps generally available to the public is illustrated by a correspondence that took place some years ago in one of our leading provincial papers with reference to the achievement of a manipulator of the hazel twig in discovering water in the Triassic rocks of the south-west of Derbyshire. No one seemed to realise that with the help of the Geological Survey Map published forty years before and the contoured Ordnance Survey Map more recently issued, it was possible for anyone who possessed a little geological knowledge and common intelligence to predict within narrow limits the depths at which it would be possible to find water at any point within the area under consideration.

When measures such as I have suggested have been adopted for rendering the publications of the Geological Survey easily comprehensible to the general public, it should be the policy of the Government to obtain for them the widest circulation, so that the information they contain should be generally known, a consummation not only desirable for its own sake as tending to increase the general interest in geology, but because it would be an important factor in developing the industries of the country.

During the war publications containing desirable information were circulated widely and gratuitously by the authorities to all public bodies concerned, and there seems no reason why the information laboriously gathered by the Geological Survey in the national interests and paid for out of the public funds should not now receive the same treatment. All Municipalities, District Councils, public libraries, colleges and schools, both secondary and elementary, should receive free copies of the Geological Survey publications dealing with the area where they are situated or with those immediately adjoining it.

When a new publication is issued the same measures should be taken to make it known locally as a private firm would employ; copies should be sent to the local press, which should be assisted to give an interesting and intelligible account of its contents, with a selection from the illustrations. There should also be a standing notice in the 'Publishers' Circular' of the Survey publications, so that local booksellers may know where to apply for them. I am told that at the present they are sometimes completely ignorant on the subject.

Every facility should, of course, be afforded to the public to make use of the Survey publications. They should not only be on sale at the post offices in the areas to which they relate, but it should also be possible to borrow folding mounted copies of the maps as well as bound copies of the explanations and memoirs, on making a deposit equal to their value. When they were no longer required, the amount of the deposit, less a small charge for use, would be repaid on their return to the same or any other post office and the production of the receipt for cancellation. It would thus be possible, when traversing any part of the country, to consult in succession all the Geological Survey publications of the districts passed through. This system would also enable the permanent residents to refer to the more expensive hand-coloured maps, including the 6-inch manuscript maps, at a comparatively small cost.

The preparation and printing of the explanations of the Survey Maps, and the increase in the numbers printed of other publications, would obviously involve additional expenditure. This would be to some extent set off by increased sales; but even if there were a net loss on the balance, it would be worth while if it enabled the fullest advantage to be taken of the expenditure incurred in any event by the Survey in investigating the mineral resources of the country.

The Survey publications should be illustrated in every museum and school in the districts with which they deal by small collections showing the characters of the local rocks, and of the minerals and fossils that occur in them, and care should be taken to see that these collections are maintained in good order and properly labelled.

It would be a good plan for the Survey to appoint a local geologist, an amateur or member of the staff of a university or college, in every area of twenty or thirty square miles [1] to act as their representative and as a centre of local geological interest. He would be expected to give his assistance to other local workers who stood in need of it. He would receive little official remuneration, but inquirers in the neighbourhood would be referred to him, and where commercial interests were involved he would, subject to the sanction of the Central Office, be entitled to charge substantial fees for his advice. He would report to the Survey any event of geological importance in the area of which he was in charge—whether it was the discovery of a new fossiliferous locality, the opening of a new quarry,[2] the sinking of a well, or the commencement of boring operations. Many of these matters would be adequately dealt with by local workers, but in other cases it might be desirable for the Survey to send down one of their officers to make a detailed investigation.

One of the most important duties of the Survey, or its local representative, would be to see that the records of well-sinkings and borings are properly kept, and that where cores are obtained the depth from which each was raised is accurately recorded. At the present time the officers of the Survey make every effort to see that this is done, but they have no legal power to compel those engaged in such operations to give the particulars required. Equally important is a faithful record of the geological information obtained in prospecting or mining operations. This is especially necessary where a mine is abandoned.[3] If care is not then taken to see that all the information available is accurately recorded, it may never be possible later to remedy the failure to do so.

Probably these objects would be much facilitated if engineers in charge of boring or mining operations had sufficient knowledge of geology and interest in its advancement to make them anxious to see that no opportunity was lost of observing and recording geological data. This would be in most cases ensured if every mining student were required to carry out geological research as part of his professional training. It is now recognised that no education in science can be considered to be up to University standard if it is limited to a passive reception of facts and theories without any attempt to extend, in however humble a way, the boundaries of knowledge. In the case of geology such research will naturally in most cases take the form of observations in the field. The important point is that the work must be original, on new lines, or in greater detail than before, and not a mere confirmation of published results. It is only by the consciousness that he is accomplishing something which has not been done before that the student can experience the keen pleasure of the conquest of the unknown and acquire the love of research for its own sake.

At present it is disheartening to realise how few of those who have received scientific instruction understand the obligations under which they lie of themselves contributing to the growth of knowledge. If they have once had the privilege of achieving individual creative work they will henceforward desire to take advantage of every opportunity of continuing it.

There is one respect in which geological workers suffer a heavy pecuniary handicap—the cost of railway fares. This affects both the staff and students of colleges, as well as local workers who are extending their radius of work—an inevitable necessity in the investigation of many problems. It also seriously interferes with the activity of local Natural History Societies and Field Clubs, the Geological Societies and Associations of the great provincial towns, and,

[1] I am afraid that in many parts of the country there are so few amateur geologists that this area would have to be increased, at any rate at first.

[2] It is very desirable that arrangements should be made for the co-operation of the Geological Survey or their local representatives with the Inspectors of Quarries appointed by the Home Office, and that the annual official list of quarries should describe the rocks which are worked, not only by their ordinary economic designations, but also by their recognised geological descriptions.

[3] Those engaged in mining are already required to furnish mining plans to the Mining Record Office, but there is no obligation to give any geological information that may have been obtained. This office was formerly attached to the Geological Survey, but was transferred some years ago to the Home Office.

above all, that focus of amateur geological activity—the Geologists' Association of London. It is difficult to exaggerate the importance of these agencies in the promotion of geological education. Both professional and amateur geologists are deeply indebted to the excursions which are in most cases directed by specially qualified workers, with whom it is a labour of love. At the same time one of their most valuable results is the creation of interest in scientific work in the localities that are visited. Now that the railways are, if report speaks truly, to be nationalised, or at any rate controlled by the State, the claims of scientific work carried out without reward in the national interest to special consideration will surely not be ignored. All questions as to the persons to whom such travelling facilities should be extended and the conditions that should be imposed may safely be left to the decision of the Geological Survey, which has always had the most friendly and sympathetic relations with private workers and afforded them every facility and assistance, which their comparatively limited staff and heavy duties permitted.

It is impossible to speak in too generous terms of the Geological Survey [4] and its succession of distinguished chiefs (the last of whom, I am glad to say, is with us to-day), or of the work it has accomplished, in spite of somewhat inadequate financial support from the powers that be, who have taken every precaution that the Honours graduates who join its ranks should do so for the pure love of science and not for the sake of worldly advantage. With increased staff and less straitened finances the Survey would be in a position, not only to discharge the additional duties my suggestions would impose on them, but to extend still further the sphere of their usefulness. There is, for instance, at the present time a very urgent need for the provision of further facilities for the analysis of rocks and minerals to assist and complete the researches both of the official surveyors and of private persons engaged in research. The work is of a very special character, and the number of those who have given sufficient attention to it and understand its difficulties and pitfalls is very limited. The chemical staff at our Universities are chiefly concerned with organic chemistry, and private analysts devote themselves mainly to the examination of economic products. The effect of a hasty excursion of workers of either of these categories into the analysis of such complex silicates as augite or biotite or any of our ordinary igneous rocks is apt to be disastrous, only exceeded in this respect by the results obtained when, as not infrequently happens, a student is given a similar task by way of practice. A certain amount of good work is undoubtedly done in College laboratories, but it is very little in comparison with what is needed.[5]

At present the analytical work of the Survey is organised on a very modest scale in comparison with the *personnel* and equipment of the laboratory of the United States Geological Survey, though the quality of the work has been as a rule in recent years quite as high. There are two analytical chemists attached to the Geological Survey, and some of the other members of the staff are capable of doing good analytical work. The demand, however, for analyses for economic purposes is so great that it is impossible to carry out all the analyses that would be desirable in connection with the purely scientific work of the Survey itself. There is consequently no possibility of their being able to assist private investigators.

Strictly speaking, the individual minerals of a rock should be separately analysed and their relative amounts determined, but this is at present a counsel of perfection that we cannot hope to attain; and when the difficulty of obtaining pure material, especially in the case of fine-grained rocks, and the zoned character of practically all complex rock-forming minerals are considered, it is seen that intrinsically it is not quite so important as it would seem to be at first sight. The bulk analysis, intelligently interpreted in connection with the actual

[4] Since 1905 the Irish Survey, a small but enthusiastic band led by one of the most broad-minded of modern geologists, has been separated from that of the remainder of the country.

[5] I should like to refer in this connection to the excellent analytical work of Dr. H. F. Harwood, of the Chemical Department of the Imperial College of Science and Technology.

mineral composition of the rock as revealed by the microscope, is, in fact, at present the most practical method of determining the composition of the minerals. I need scarcely say that volatile constituents still retained by the rock should be separately determined, and the amount reported as water should not include any other substance given off at the same time.

In the absence of facilities for obtaining rock analyses, petrological work in this country is at present seriously handicapped. A striking illustration of the inadequate provision for analyses is revealed in the fact that for the whole of the early Permian granitic intrusions in the south-west of England, covering nearly 2,000 square miles, and including numerous different types and varieties, there are only four analyses in existence, and of these two are out of date and imperfect. This is all the more remarkable in view of the fact that these rocks are closely connected with the pneumatolytic action that has given us almost all the economic minerals of the south-west of England, comprising ores of tin, tungsten, copper, lead, and uranium, as well as kaolin. If the Survey, by increasing its staff of analysts, were in a position, not merely to multiply the number of analyses illustrating its own work, but to help others engaged in research, they would only be proceeding on lines which have long since been followed in some of our Dominions.

Another direction in which the work of the Survey could with advantage be extended is in the execution of deep borings [6] on carefully-thought-out schemes by which a maximum of information could be obtained. Both in Holland and Germany borings have been carried out to discover the nature of the older rocks beneath the Secondary and Tertiary strata, and Prof. Watts, in his Presidential Address to the Geological Society in 1912 (Proc. Geol. Soc. pp. lxxx.-xc.), dwelt on the importance of exploring systematically the region beneath the wide spread of the younger rocks that cover such a great extent of the east and south of England. Prof. Boulton, my predecessor in this Chair, has endorsed this appeal, but nothing has been done or is apparently likely to be done in this direction. It seems extraordinary that no co-ordinated effort should have been made to ascertain the character and potentiality of this almost unknown land that lies close beneath our feet and is the continuation of the older rocks of the west and north to which we owe so much of our mineral wealth. It is true that borings have been put down by private enterprise, but, being directed only by the hope of private gain and by rival interests, they have been carried out on no settled plan, and the results and sometimes the very existence of the borings have been kept secret. The natural consequences of this procedure have been the maximum of expense and the minimum of useful information.

Unfortunately in recent years percussion or rope boring, which breaks up the rock into fine powder, has more and more, on account of its cheapness, replaced the use of a circular rotating drill which yields a substantial cylindrical core that affords far more information as to the nature of the rocks and the geological structure of the district. If private boring is still to be carried on, the adoption of the latter procedure should be insisted on, even if the difference of cost has to be defrayed by the Government. It is quite true that a considerable amount of useful information can be collected by means of a careful microscopic examination of the minute fragments which alone are available for study, so that the nature of the rocks traversed can be recognised; but the texture of the rock is destroyed, as well as any evidence which might have been available of its larger structures and stratigraphical relations and almost all traces of fossils. It is, too, impossible to tell with certainty the exact depth at which any particular material was originally located, for fragments broken off from the sides of the bore may easily find their way to the bottom.

A good illustration, and one of many that might be cited, of the misdirected

[6] I have not space to deal here with the shallow borings in soft strata which have been so successfully conducted on the Flanders front during the war by Captain W. B. R. King, of the Geological Survey. Similar borings have been already carried out by the Survey on a limited scale, but in the light of the experience that has now been gained we may look for a widely extended use of the method both by private workers and by the Survey officers.

energy that is sometimes expended in prospecting operations, was afforded a few years ago by a company that put down a boring for oil through more than a thousand feet of granite without being aware of the nature of the rock that was being traversed. In this case a percussion drill was employed, but a few minutes' examination of the material should have enabled the engineer in charge, supposing he had even an elementary knowledge of geology, to save hundreds of pounds of needless expenditure. The sum total of the funds which have been uselessly expended in this country alone in hopeless explorations for minerals, in complete disregard of the most obvious geological evidence, would have been sufficient to defray many times over the cost of a complete scientific underground survey.

If research is to be carried out economically and effectively, it must be organised systematically and directed primarily with the aim of advancing knowledge. If this aim be well and faithfully kept in view, material benefits will accrue which would never have been thought to be sufficiently probable to warrant the expenditure of money on prospecting.

It is, however, not only in the areas occupied by Secondary or Tertiary rocks that systematic boring is urgently needed. There are many other localities where important information as to the structure of the rocks could probably be obtained in this manner. Opinion is very much divided as to the relation of the Devonian to the older rocks in South Devon and Cornwall,[7] but there is little doubt that a series of judiciously placed borings would solve the problem without difficulty. In North Devon and West Somerset, the question as to whether the Foreland Grits are a repetition by faulting of the Hangman Grits could also be settled at once by borings in the Foreland Grits and in the Lynton Beds.

In the North of England, again, there are many points where the strata exposed at the surface are low down in the Carboniferous, and it would be comparatively easy to ascertain the nature of the earlier rocks beneath them, with regard to which we are much in need of information.[8]

It would be easy to cite other cases where information of considerable geological value could be obtained by boring at comparatively small expense, and would in all probability in the majority of cases lead ultimately to results of economic importance.

It is obviously only right that any commercial advantages resulting from investigations carried out at the public cost should accrue to the State, and, if this principle were adopted, expenditure by the Government or geological research on the lines I have suggested would be sooner or later recouped by the mineral wealth rendered available to the community.

It is not, however, on terra firma alone that such investigations may be usefully carried out. The floors of the shallow seas that separate these islands from one another and from the continent of Europe are still almost unknown from the geological standpoint, although their investigation would present no serious difficulties. Joly[9] has described an electrically driven apparatus which, when lowered so as to rest on a hard sea floor, will cut out and detach a cylindrical core of rock, and retain it till raised to the surface. Subsequently

[7] I have already referred to the economic importance of this area. The desirability of ascertaining its true geological structure is too obvious to need emphasis here.

[8] The recent borings for mineral oil in the Carboniferous rocks of Derbyshire were put down largely by means of public funds, and such success as they have attained has been due to the fact that they were directed by expert geologists; but there can be little doubt that, if they had been carried out as part of a carefully-thought-out scheme of underground exploration wherever it was needed to elucidate the structure of the country, economies would have been effected and the sum total of our knowledge even from the economic standpoint would have been far greater. It is a pity that these borings have been carried out by means of the percussion process. It is, however, usually employed in borings for oil—in America almost exclusively—and in war-time its greater speed was no doubt an important factor in the decision to resort to it.

[9] 'On the Geological Investigation of Submarine Rocks,' *Sci. Proc. Roy. Dubl. Soc.*, vol. viii., pp. 509-524, 189.

he invented a still more ingenious device,[10] in which the force of the sea-water entering an empty vessel is substituted for electrical power, but unfortunately neither the one or the other has actually been tried or even constructed.

Meantime, however, vertical sections up to 80 cm. (2 ft. 7½ in.) of the mud of the deep seas have actually been obtained in iron tubes attached to sounding apparatus employed in the course of the voyage of the Gaussberg. These reveal a succession of deposits of which the lower usually indicate colder water conditions than the upper, and have been referred for that reason to the last Glacial Period.[11]

In many places rock fragments are dredged up by fishing boats. These should of course be used with caution in drawing conclusions as to the distribution of rocks *in situ* on the sea bottom, as such fragments may have been transported when embedded in ice sheets or in ice bergs or other forms of floating ice, or entangled in the roots of floating trees; but where the rock-fragments can be shown to have a definite distribution, as in those described by Grenville Cole and Thomas Crook from the Atlantic to the west of Ireland,[12] and by R. H. Worth from the western portion of the English Channel,[13] they may be regarded as affording trustworthy information as to the geology of the area.

There seems every reason to believe that advances in submarine geology will not be of only scientific interest, but will bring material benefits with them. Even at present the working of coal seams and metalliferous veins has been extended outwards beyond low-water mark, and, if evidence should be forthcoming that valuable deposits underlie the shallower waters of the North Sea at any point, there is no reason to doubt that mining engineers would find means of exploiting them. It seems quite possible that off the shores of Northumberland and Durham there are, in addition to extensions of the neighbouring coal-field, Permian rocks containing deposits of common salt, sulphate of calcium (gypsum and anhydrite), and, above all, potash salts comparable to those at Stassfurt, which have proved such a source of wealth to Germany.

No less important than the work of the Geological Survey is that of our great national museums. I have already alluded to the need for local collections to illustrate the geology of the areas in which they are situated. The museums of our larger cities and our universities will naturally contain collections of a more general character, but it is to our national museums that we must chiefly look for the provision of specimens to which those engaged in research can refer for comparison, and it is imperative that they should be maintained in the highest state of efficiency, if the best results are to be obtained from scientific investigations in this country. The ability and industry of the staff of the Mineral and Geological Departments of the Natural History Museum are everywhere recognised, as well as their readiness to assist all those who go to them for information, but in point of numbers they are undeniably insufficient to perform their primary task of examining, describing, arranging, and cataloguing their ever-increasing collections so as to enable scientific workers to refer to them under the most favourable conditions.[14] Even if the staff were doubled, its time would be fully occupied in carrying out these duties, quite apart from any special researches to which its members would naturally wish to devote themselves. The additional expense incurred by the urgently needed increase of the museum establishment would be more than repaid to the country in the increased facilities afforded for research.

[10] 'On the Investigation of the Deep Sea Deposits,' *Sci. Proc. Roy. Dubl. Soc.*, vol. xiv. pp. 256-267, 1914.

[11] E. Philippi; 'Die Grund-proben der deutschen Südpolar Expedition,' 1901-3, vol. ii., pp. 416-7 and 591-598.

[12] 'On Rock-specimens Dredged off the Coast of Ireland and their Bearing on Submarine Geology,' *Mem. Geol. Surv.*, Ireland, pp. 1-35, Dublin, 1910.

[13] 'The Dredgings of the Marine Biological Association' (1895-1906) as a contribution to the knowledge of the Geology of the English Channel.—*Journ. Marine Biol. Assoc.*, vol. viii., pp. 118-188. 1908.

[14] Even the number of skilled mechanics is quite insufficient, though their work is urgently needed. In the Geological Department provision is only made for two, and at present but one is actually at work.

There is room, too, for a considerable extension in the scope of the activity and usefulness of our museums in other directions, and more especially in the provision of typical lithological collections illustrating the geology of different parts of the British Empire and of foreign countries.

So far as the United Kingdom is concerned, this requirement has been admirably fulfilled in the museums attached to the Survey Headquarters in London, Edinburgh, and Dublin, and there is a smaller collection of the same nature, excellent in its way, at the Natural History Museum. But to obtain a broad outlook it is essential that the attention of geological workers should not be confined to one country, however diversified its rocks may be, and it is impossible to assimilate effectively publications dealing with the geology of other parts of the world without being able to refer to collections of the rocks, minerals, and fossils described.

The rocks, for instance, of the Dominion of South Africa are of the greatest scientific and economic interest, and many important communications have been published with regard to them. They present at the same time many features which distinguish them from European types, but I am not aware of any museum in this country where they are adequately illustrated.

Such collections should include not only rock specimens in the ordinary sense of the term, but also examples of metalliferous veins and other mineral deposits which present important distinctive features.

In the Imperial Institute there are at the present time collections from most of the different constituent parts of the British Empire, which fulfil to a certain extent these requirements, and they have been employed by myself and others in demonstrations to the Geologists' Association in illustration of the geology of Peninsular India and different parts of Africa; but they are very incomplete, having been collected with the view of exhibiting, not so much the character of the rocks and mode of occurrence of the minerals, as the economic resources of the British Empire.

This is, of course, a function of the very greatest importance, but collections of minerals of intrinsic economic significance gathered together to assist in the development of the resources of the Empire should be organised on a different plan. They should be arranged, not according to the areas in which they occur, but with reference to the products obtained from them. The object of such collections is to enable those who are in want of materials for commercial purposes to ascertain where they can be obtained, and of what quality and at what price. For this purpose different samples of the same or similar ores or other products should be placed together irrespective of their origin, and each specimen should be accompanied by an assay or analysis, and such information with regard to its source and mode of occurrence as will enable the inquirer to form an opinion as to whether it will be likely to satisfy his requirements.

The lithological and palæontological collections which I am now advocating should, on the other hand, be arranged so that each group of specimens illustrates an area possessing distinctive geological features. Little has, hitherto, yet been done in this direction. The Mineral Department of the Natural History Museum possesses a large and extensive collection of foreign and colonial lithological specimens arranged according to localities, which is too little known, but it is naturally very unequal and incomplete, some countries being comparatively well represented and others scarcely at all. The Geological Department of the Museum is well provided with palæontological specimens, but these are arranged according to their biological affinities, and they might well be supplemented by a series of typical collections illustrating the fauna and flora of the more distinctive horizons in different areas. This is all the more important, as the mode of preservation may be very different in different places. It is probable that the geological surveys of British Dominions and Dependencies and of foreign countries would in many cases be able to supply such collections of rocks, mineral deposits, and fossils as I have suggested. Where this is not possible, the only practicable means of obtaining really typical collections is to despatch a representative of the Museum, preferably one of its own officers, to make one himself. The provision of such facilities for the study of the geology of other lands is especially desirable in London in view

of the number of students of mining and economic geology who receive their training in this country and ultimately go out into the world to find themselves face to face with problems in which a true understanding of the local geology is absolutely essential.

I shall not discuss here the important subjects of the indexing of geological literature and the preparation of abstracts of current publications. The former is already being efficiently dealt with by the Geological Society, and the latter will, I trust, be provided for in some way in the immediate future.

I now proceed to indicate some lines along which it seems to me probable that there are opportunities for progress in geological research.

In the investigation of the sedimentary rocks attention has been usually directed mainly to the larger and more obvious features, and these have sufficed to afford considerable insight into the conditions which prevailed when they were laid down. The detailed study of the minor structures or texture of these rocks by lens and microscope has, on the other hand, been comparatively neglected, though it is capable of affording us valuable information that could be obtained in no other way. There are, however, I need hardly say, important exceptions, the classical researches of Sorby extending over more than half a century, the investigations of Hutchings on the argillaceous rocks, and much useful work in recent years on the mineral constituents and microzoa of the sedimentary rocks generally. But, although individual sediments have been carefully studied, few, if any, attempts have been made to carry out a detailed examination of the successive beds of a stratigraphical succession comparable to the systematic zoning by means of fossils which has yielded such valuable results.

Not only ought the texture and composition of the individual laminæ to be patiently studied to obtain information as to the exact manner of their deposition, but attention should be more especially directed to the character of the transition by which one layer gives place to another, so as to determine, if possible, the cases where there has been a gradual passage without a break, and those in which there has been a pause in the deposition of greater or less duration, or even a removal of material, although nothing in the nature of an unconformity, however slight, can be detected. Even in apparently uniform deposits, such as chalk and clay, variations in texture and composition may be brought out by special treatment and reveal interesting details of the conditions under which they were deposited.

It is of special importance to recognise and examine in detail the occurrence of rhythmic repetitions of a similar succession of sedimentary materials and characters. A single cycle in such a succession may be only a twentieth of an inch in thickness, as in the case of ferruginous banding in the Lower Hangman Grits at Smith's Combe in the Quantocks, or may include thirty or forty feet of strata, as in the Caithness Flags. Rhythms have been described from the pre-Cambrian of Finland, the Ordovician of North America,[15] the Permian of Stassfurt,[16] the Cretaceous of Arkansas,[17] and the Quaternary of Scandinavia and Palestine, and many more, no doubt, occur in the stratigraphical succession of different countries. It would probably be found that a similar repetition occurs in fine terrigenous deposits off the coast of tropical countries where there is a well-defined alternation of wet and dry seasons. In some places minor cycles may be superimposed on larger, as in the case of the Skerry Belts described by Bernard Smith[18] in the Upper Keuper of East Nottinghamshire. The general question of the significance of such rhythms of stratification must, however, be reserved for another occasion.

It is more difficult to arrive at the true interpretation of the phenomena

[15] Joseph Barrell; *Bull. Geol. Soc. Am.*, vol. xxviii., pp. 789-90, 1917.
[16] C. Ochsenius; *Zeitsch. für practische Geologie*, vol. 13, p. 168, 1905.
[17] G. K. Gilbert; *Journ. of Geology*, vol. iii., pp. 121-127.
[18] *Geol. Mag.*, 1910, pp. 303-305.

presented by the endogenetic rocks[19] which have come into existence by the action of the forces of earth's interior, for the conditions of temperature and pressure under which they were formed, whether they are igneous rocks in the narrower sense, or mineral veins, or metamorphic in origin, were widely different from those with which we are familiar. Under such circumstances the ultimate physical principles are the same, but the so-called constants have to be determined afresh, and a new chemistry must be worked out. It is necessary, therefore, as far as possible, to reproduce the conditions that prevailed—a task which has been courageously undertaken and to a considerable extent accomplished by the Geophysical Laboratory of the Carnegie Institute at Washington.

By artificial means temperatures and pressures have been already produced far higher than those that were in all probability concerned in the evolution of any of the rocks that have been revealed to us at the surface by earth-movements and denudation, for it is unlikely that in any case they were formed at a greater depth than five or six miles, corresponding to a uniform (or, as it is sometimes termed, hydrostatic) pressure of 2,000 or 2,400 atmospheres, or at a greater temperature than 1,500° C. Indeed, it is probable that the vast majority of igneous and metamorphic rocks, as well as mineral veins, came into existence at considerably less depths, and at more moderate temperatures. It is true that most of the rock-forming minerals crystallise from their own melts at temperatures between 1,100° C. and 1,550° C., but they separate out from the complex magmas from which our igneous rocks were formed at lower temperatures, rarely much exceeding 1,200° C., and frequently considerably less.[20]

It has been found possible at the Geophysical Laboratory to maintain a temperature of 1,000° C. or more under a uniform pressure of 2,000 atmospheres for so long a time as may be desired, and, what is equally important, the temperature and pressure attained can be determined with satisfactory accuracy, the temperature within 2° C., and the pressure within 5 atmospheres.

It has been ascertained that such uniform pressure as would ordinarily be present at the depths mentioned does not directly affect the physical properties of minerals to anything like the same extent as the difference between the temperature prevailing at the earth's surface and even the lowest temperature at which igneous rocks can have been formed. It has, however, a most important indirect action in maintaining the concentration in the magma of a considerable proportion of water and other volatile constituents[21] which have a far-reaching influence in lowering the temperature at which the rock-forming minerals crystallise out, in other words, the temperature at which the rock consolidates, and in diminishing the molecular and molar viscosity of the magma, thus facilitating the growth of larger crystals and the formation of a rock of coarser grain. They must also be of profound significance in determining the minerals that separate out, the order of their formation, and the processes of differentiation in magmas.

It is, therefore, obvious that any conclusions derived from the early experiments which were carried out with dry melts at normal pressures must be received with very considerable caution. Nor does much advance appear to have been made, even at the Geophysical Laboratory, in experiments with melts containing large amounts of volatile fluxes, and yet, if we are to reproduce even approximately natural conditions, it is absolutely necessary to work with magmas containing a proportion of these constituents, and especially water, equal in weight to at least one-third or one-half of the silica present. This will obviously present considerable difficulties, but there is no reason to doubt that it will be found possible to surmount them.

[19] T. Crook; *Min. Mag.*, vol. xvii., p. 87, 1914.

[20] It is probable that the temperatures recorded in some lavas higher than the melting point of copper, which is well over 1,200° C., are due to chemical reactions, such as the oxidation of hydrogen, carbon monoxide, ferrous oxide, and perhaps sulphur. See Day and Shepherd, *Bull. Geol. Soc. Amer.*, vol. xxiv., pp. 599-601, 1913.

[21] John Johnston, *Journ. Franklin Inst.*, Jan. 1917, pp. 14-19.

A much more formidable obstacle in realising the conditions under which rocks are formed is the small scale on which our operations can be carried on. There are important problems connected with the differentiation of magmas, whether in a completely fluid or partly crystallised state, under the action of gravitation, for the solution of which it would seem for this reason impossible to reproduce the conditions under which Nature works. Instead of a reservoir many hundreds of feet in depth, we must content ourselves in our laboratory experiments with a vertical range of only a few inches. There are, however, other phenomena that require investigation and that involve a great difference of level in their operation, but do not take place at such elevated temperatures. Such are some of the processes of ore deposition or transference, especially secondary enrichment. Here, with the friendly assistance of mining engineers, but at the cost of considerable expenditure, it might even be possible to experiment with columns several thousand feet in vertical height.

In any attempt to reproduce the processes of metamorphism other than those of a purely thermal or pneumatolytic character, or to imitate the conditions that give rise to primary foliation, we must consider the effects of non-uniform or directed pressure involving stresses that operate in definite directions and result in deformation of the material on which they act. Unlike uniform pressure which usually raises the crystallisation point, directed pressure may lower it considerably and thus give rise to local fusion and subsequent recrystallisation of the rock.[21] At the same time it profoundly modifies the structure, resulting in folds and fractures of every degree of magnitude. One of the most pressing problems of geology at the present moment is to determine the effects of directed pressure in its operation at different temperatures, and in the presence of different amounts of uniform pressure, a factor which has probably an important influence on the result, which must also depend on the proportion and nature of the volatile constituents which are present, as well as on the time during which the stresses are in operation. There seems no reason why valuable information should not be obtained on all those points by properly conducted experiments.

The time element in the constructive or transforming operations of Nature cannot, of course, be adequately reproduced within the short space of individual human activity, or, it may be, that of our race; but I am inclined to think that, even in the case of metamorphic action, the importance of extremely prolonged action has been exaggerated.

In attempting to imitate the natural processes involved in the formation and alteration of rocks and mineral veins, we require some means of ascertaining when we have approximately reproduced the conditions which actually prevailed. It is not sufficient to bring about artificially the formation of a mineral occurring in the rocks or mineral deposits under investigation, for the same mineral can be reproduced in many ways. It is, however, probable that a mineral produced under different conditions is never identical in all its characters. Its habit, or the extent to which its possible faces are developed (a function of the surface tension), the characters of the faces which are present, its twinning, its internal structure, inclusions and impurities, all vary in different occurrences, and the more closely these can be reproduced, the greater the assurance we obtain that an artificial mineral has been formed under the same conditions as the natural product.

For this purpose it is above all necessary that there should be in the first place a systematic comparative study of these characters and of the association in which they are found. The results thus obtained should be of the greatest value in indicating the directions along which experimental work would be most probably successful. They should, of course, be supplemented by laboratory

[21] See J. Johnston and L. H. Adams, *Jour. Am. Chem. Soc.*, vol. xxxiv., p. 563 (1912); *Am. J. Sci.*, vol. xxxv., p. 206 (1913); A. Harker, *Proc. Geol. Soc.*, vol. lxxiv., pp. 75-77 (1919). It is interesting to note that similar principles apply to the pseudo-fluidity induced in clay by directed pressure. See P. M. Crosthwaite, *Proc. Inst. C.E.*, December 19, 1916, p. 149; *Journ. and Trans. Soc. Eng.*, vol. x., pp. 82-86, 92-94, 1918; Alfred S. E. Ackermann, *ib.* pp. 37-80, 102-107.

studies of the relations of such subsidiary crystallographic characters to the environment in the case of crystals which can be formed under normal conditions of temperature and pressure, and therefore under the immediate observation of the experimenter. Some work has, in fact, already been done on the effects on these characters of the presence of other substances in the same solution.

In the study of the secondary alterations of metalliferous deposits, especially those which consist of the enrichment of mineral veins by the action of circulating solutions, either of atmospheric or intratelluric origin, the study of pseudomorphs gives, of course, valuable assistance in determining the nature of the chemical and physical changes that have taken place.

A successful solution of the problem of the exact conditions under which deposits of economic importance are found would be of incalculable value in facilitating their discovery and exploitation, and would be the means of saving a vast amount of unnecessary labour and expense.

The problem of the structure and nature of the earth's interior, inaccessible to us even by boring, would seem at first sight to be well nigh insoluble, except as far as we can deduce from the dips and relations of the rocks at the surface their downward extension to considerable depths. We can, however, gain important information about the physical condition of the deeper portions from the reaction of the earth to the external forces to which it is subjected, and still more from a study of the 'preliminary' earthquake tremors that traverse it, the time occupied in their passage, and the difference in intensity of those that follow different paths. These methods are, however, not applicable to the earth's crust. Its physical characters appear to be distinct from those of the interior, but very little is as yet definitely known about them, except of course in the neighbourhood of the surface, and for this reason they are usually ignored in calculating the paths of tremors traversing the earth. It seems to be separated from the deeper portions of the earth by a surface of discontinuity at which earthquake vibrations travelling upwards towards the surface may be reflected. Calculations based on the total time taken by these reflected waves to reach the surface after a second passage through the earth's interior appear to indicate that this surface of discontinuity, whatever its nature may be, is at a depth of about twenty miles, though there can be little doubt that this depth varies considerably from point to point.

The main earthquake vibrations appear to follow the curvature of the earth, and to be confined to its crust, instead of traversing the interior, as is the case with the preliminary tremors. In these vibrations a period of about seventeen or eighteen seconds is usually predominant, and is believed to be due to the natural period of vibration of the earth's crust. Wiechert [22] assumes that there is a node halfway down and a free movement above and below, so that the full wave length would be twice the thickness of the earth's crust. Assuming a velocity of propagation of $3\frac{1}{2}$ km. per second, he calculates the depth of the crust to be approximately 30 km. There seems, however, to be no warrant for supposing that the lower surface of the crust is capable of free vibration. The fact that, not only waves of compression, but waves of distortion can traverse it shows that it must possess very high rigidity so far as forces of brief duration are concerned. The lower surface should therefore be regarded as a node, and only the upper as capable of free movement, so that the whole would correspond to a quarter of a wave length. On the other hand, the velocity of $3\frac{1}{2}$ km. per second, which is that of the propagation of waves round the earth's crust, in all probability a complex process, is not the same as the true velocity of vibrations passing upwards and downward through the earth's crust. Those with a period of about 18 seconds appear to consist partly of horizontal vibrations and partly of vertical; the former would seem to correspond to waves of distortion, and the latter to waves of compression. The velocity of the former would probably be about 4 km. and the latter 7 km. per second, corresponding to the thicknesses of

[22] *Göttingen Nachrichten*, 1907, pp. 468-9.

18 km. and 31½ km. (eleven and twenty miles). There is some evidence in the case of a distant earthquake of a period approximating to 30 km. per second, which would correspond, with waves of distortion, to a thickness of 30 km. (nineteen miles). However in the present state of our knowledge of these vibrations such calculations are only of speculative interest.

There must be numerous surfaces of discontinuity in the earth's crust in addition to that forming its lower limit. Such would be the boundaries between great tracts of granite or granitoid gneiss and the basic rocks that in all probability everywhere underlie them; the surface dividing gneisses and crystalline schists from unmetamorphosed sediments overlying them unconformably; that between hard Palæozoic rocks and softer strata of later age; and the surfaces of massive limestones or sills. Wiechert observed at Göttingen, at the time of the Indian earthquake of April 4, 1905, small horizontal vibrations, superimposed on the others, with a period of only 1½ seconds. He believed that these were due to horizontal distortional vibrations of the local sandstone formation with a node at its basal surface. He found the velocity of similar vibrations at the surface to be 250 m. per second, and thence calculated the depth of the sandstone stratum to be 90 m.[23] No doubt similar correlations of terrestrial vibrations and the structure of the earth's crust may be made in other cases.

It deserves consideration, however, as to how far it may be possible to add to our knowledge of the earth's crust by experimental work with a view of the determination of surfaces of discontinuity by their action in reflecting vibrations from artificial explosions, a procedure similar to that by means of which the presence of vessels at distance can be detected by the reflection of submarine sound waves. The ordinary seismographs are not suited for this purpose; the scale of their record, both of amplitude and of time, is too small for the minute and rapid vibrations which would be expected to reach an instrument situated several miles from an explosion, or to distinguish between direct vibrations and those that may arrive a second or two later after reflexion at a surface of discontinuity. As the cylinder on which the record is made would be only in motion while the experiment was in progress, there would be no difficulty in arranging for a much more rapid movement. At the same time it would be desirable to dispense with any arrangement for damping the swing of the pendulum, which would be unnecessary with small and rapid vibrations, and would tend to suppress them. It is possible that it might be better to employ a seismograph which records, like that devised by Galitzin shortly before his death, variations of pressure expressing terrestrial acceleration, instead of one which records directly the movements of the ground. It would, however, probably be found desirable to substitute for the piezo-electric record of pressure employed by Galitzin a record founded on the effect of pressure in varying the resistance in an electric circuit. This is, in fact, the principle of the microphone and most modern telephone receivers, but quantitatively they are very unreliable. This would not matter so much for the present purpose, where the time of transmission is the most important feature in the evidence, but satisfactory results even in this respect appear to be given by Brown's liquid microphone, from which the record could be taken, if desired, by means of the reflection of a mirror, attached to the needle of the galvanometer.

Evidence of the structure of the earth's crust is also afforded by observations on the direction and magnitude of gravitation which have been carried out in considerable detail in India and the United States—especially in the neighbourhood of great mountain ranges. At the present time the problem of correlating the variations observed with the underground structure is only in an embryonic stage. It is probable that our greatest hope of advancing researches with this object is by detailed work in areas which present no marked orographical features, and where the geological structure is already fairly well ascertained.

The same remarks apply to the results obtained by magnetic surveys. Apart from the marked effect of masses of magnetite in the immediate neighbourhood of the surface, local magnetic irregularities appear to be mainly determined by

[23] *Göttingen Nachrichten*, 1907, pp. 467-8.

the presence of basic igneous rocks,[24] but there seems to be considerable room for research as to the relation between these phenomena and the form and composition of an igneous intrusion.

In this review of some of the possibilities of geological research I cannot claim to have done more than touch the fringe of the subject. In every direction there is room for the development of fresh lines of investigation, as well as for renewed activity along paths already trodden. Whether my particular suggestions prove fruitful or not, they will have served their purpose if they have stimulated anyone to look for new fields of work.

Postcript.—Since this Address was written, I have learned that Professor Kendall has from time to time made valuable suggestions with regard to the association of the Survey with local workers, more especially the geological staff and students of our colleges.

The following Papers were then read :—

2. *The Tertiary Beds of Bournemouth and the Hampshire Basin.* *By* Dr. William T. Ord, *F.G.S.*

The physical history of these Eocene beds is briefly as follows :—The gradual uprising of the bed of the Cretaceous sea was in this district accompanied by a planing off of the highest zones to some distance down the Belemnitella zone. This left an eroded surface on which the earliest Tertiary beds (Woolwich and Reading) were deposited. Flint pebbles, once rolled in chalk-enclosed coves, form a basement bed. As the new chalk land-surface developed, a west-to-east drainage system rapidly formed, which during the next period—London Clay—took the form of a vast river, rivalling the Ganges or Amazon. It entered the sea near Sheppey, in Thanet, where tropical vegetable flora and estuarine fauna have left abundant remains. Here the fluviatile beds—of sand and clay, with a few pebble bands—are almost unfossiliferous. This is true locally for each division of the Tertiaries, following the usual rule of fluviatile deposits, the nearer the mouth the more organic remains, the nearer the source the fewer. Since Bournemouth occupies a place far from Sheppey, fossils are few or wanting. The exception are leaves and fruits which have been deposited in clay bottoms of backwaters and lagoons, and hence occur in lenticular patches in the cliff face.

In the succeeding beds—the Bagshots—abundant vegetable remains occur. During this period the sea continually encroached from the east, until at the close of the Bagshot period it is believed to have reached a point near the East-cliff Lift. The shingle-beds of the Bracklesham (Boscombe Sands) covering the Bagshots were a beach deposit. The succeeding Bracklesham deposits, locally known as Hengistbury Head beds, are followed by the Barton sands and clays; these are increasingly marine, and their organic remains show a marked fall of temperature from the sub-tropical climate of Bagshot age. The succeeding strata, Headon beds and Oligocene, concluded by the Bembridge Limestone, occur in the Isle of Wight and the Headons, also in the opposite coast. These were denuded off the Bournemouth area in Miocene times, except for an important outlier in Purbeck known as Creech Barrow. All these Eocene strata were deposited over a far greater area than they now occupy, and their remains have been preserved in the Thames Valley and Hampshire Basin through the protection afforded by the results of the great earth movements of Miocene and Pliocene times. The Chiltern Hills and North Downs protected the Tertiaries of the Thames Valley, and the South Downs and the Brixton anticline of the

[24] A. Hubert Cox : *Abstracts of the Proceedings of the Geological Society of London*, 1918, pp. 71-74.

Isle of Wight with the Purbeck Hills protected the Tertiaries of the Bournemouth area, forming as they do the boundaries of the Hampshire Basin. But for this fact that the Bournemouth, Bagshot and Bracklesham beds lie in the syncline of the Hampshire Basin, this area would have been stripped bare to the chalk, as have other unprotected parts of the south coast. The characteristic beauty and scenery of Bournemouth has thus happily been preserved for us, with the pines, gorse and heather which flourish on such soil. In conclusion, mention should be made of several local peculiarities of the Tertiary beds. First, that they all rapidly thin out westward. Secondly, the pipe-clay deposits of the Lower Bagshots derived from decomposition of granite to the west and brought down by the Solent River. Thirdly, the complete absence of lime, and consequently of molluscan remains, from the Woolwich and Reading beds to the base of the Bartons. This is due to prolonged percolation of surface water through the sand. No traces of the prolific shell-life of Selsey are found in the Bracklesham beds of this district.

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2. *The Lithological Succession in the Avonian of the Avon Section, Clifton.* *By* S. H. Reynolds, *Sc.D., F.G.S.*

Several previous workers have dealt with the lithology of the Avon section, and, in particular, Mr. E. B. Wethered and the late Dr. A. Vaughan. The results of the present paper are based in part on field work, in part on the study of over 200 rock slices which have been cut with the aid of grants from the University of Bristol Colston Society.

The chief rock-types occurring are the following, the horizons being alluded to under the designation adopted in Vaughan's original paper.[1]

Calcareous Rocks.

Algal limestones are abundant (*a*) in Km, (*b*) at the top of C_2, (*c*) in the lower part of S_1, (*d*) in the pisolitic beds of the lower part of S_2, (*e*) in the 'Concretionary Beds' of the upper part of S_2: this is the most important development.

Mitcheldeania and *Solenopora* are the most persistent forms ranging from the base of K to the top of S_2. *Spongiostroma* is the prevalent form in the calcite-mudstones which are so abundant in C_2 and S.

Foraminiferal Limestones: Foraminifera first begin to be fairly common in Z_2. They occur in great abundance in the upper part of S_2 and the lower part of D_1.

Coral Limestones: Zaphrentid corals play an appreciable part as limestone builders in Z_1, while bands full of *Lithostrotion martini* are most characteristic of S. Corals attain their greatest importance in D.

Crinoidal Limestones: Crinoids are abundant in K_1 and K_2, and are the greatest limestone builders throughout the whole of the Z beds.

Brachiopod Limestones are met with throughout nearly the whole section. *Spirifer*, *Orthotetes* and *Chonetes* being the most abundant Tournaisian genera, *Seminula*, *Productus* and *Chonetes* the commonest Viséan.

Ostracods are very plentiful wherever the rocks are shaly or of the calcite-mudstone type, viz.: throughout K, at the top of C_2, and in the lower part of S_1.

Oolites occur at the following levels: (*a*) in the upper part of C_1, (*b*) in the middle of S_2, (*c*) throughout D.

Siliceous Rocks.

Grits are met with only in the D beds. Chert bands occur (*a*) near the middle of Z_1, (*b*) in S_2 below the oolite, (*c*) in S_2 between the oolite and the 'Concretionary Beds.'

[1] *Q.J.G.S.*, vol. lxi. (1905).

Argillaceous Rocks.

Thick shales are met with (*a*) throughout K_1, (*b*) in upper C_2 and lower S_1, (*c*) in upper D_1 and upper D_2

Changes which have affected certain of the Rocks.

Penecontemporaneous brecciation (dessication breccias) are characteristic of all the shallow water (lagoon-phase, *Dixon*) rocks of C_2 and S.

Dolomitization proves to be considerably more widespread in the Avon rocks than had been previously supposed. The matrix of the *Petit Granit* of Z_1, Z_2 and γ is almost everywhere dolomitized. The almost complete dolomitization of C_1 and the upper part of C_2 has long been familiar. There has been considerable dolomitization in the calcite-mudstones of S_1 and lower S_2. All the chief dolomites are to be classed as contemporaneous according to the classification of Mr. L. M. Parsons.[2]

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3. *Interim Report of the Committee to Investigate the Geology of Coal Seams.*

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4. *Interim Report of the Committee on the Old Red Sandstone Rocks of Kiltorcan, Ireland.*

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5. *Interim Report of the Committee to Investigate the Flora of Lower Carboniferous times, as exemplified at a newly-discovered locality at Gullane, Haddingtonshire.*

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6. *Interim Report of the Committee to Excavate Critical Sections in the Palæozoic Rocks of England and Wales.*

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7. *Interim Report of the Committee to Excavate Critical Sections in Old Red Sandstone Rocks at Rhynie, Aberdeenshire.*—See Reports, p. 110.

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8. *Interim Report of the Committee to Consider the Preparation of a List of Characteristic Fossils.*

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9. *Interim Report of the Committee on the Collection, Preservation, and Systematic Registration of Photographs of Geological Interest.* —See Reports, p. 111.

In the afternoon a Sectional Excursion to Bournemouth Cliffs took place.

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[2] *Geol. Mag.* Dec. vi., vol. v. (1918), p. 246.

WEDNESDAY, SEPTEMBER 10.

The following Papers were read :

1. *The Mesozoic Rocks of the Bournemouth District.* *By* Sir Aubrey Strahan, *K.B.E., F.R.S.*

Th ' Isle ' of Purbeck includes a part of the healthy tract underlain by the Tertiary beds of the Hampshire Basin, a central ridge formed by the chalk which rises abruptly from beneath those beds, and, in its southern part, a hilly region underlain by Wealden, Purbeck, Portland, and Kimmeridge strata, and terminated by bold cliffs. Each formation gives rise to characteristic features in the landscape, the Portland Stone especially forming a dominant escarpment and vertical sea-cliffs.

The emergence of the chalk and underlying formations from beneath the Tertiary beds is due to an extremely sharp fold, accompanied by overthrusting. The age of the movement is proved in the Isle of Wight to have been post-Oligocene, inasmuch as the Oligocene strata are there involved in it. On the other hand, it was accomplished, and the uplifted strata were exposed to prolonged denudation, in pre-Pliocene times. The sagging of the strata which led to the formation of the Hampshire and London basins and the arching-up of the intervening Wealden anticline are attributable to the same period and to the same earth-movement.

So energetic a movement, coming into activity at so late a geological age, had a profound influence upon the physical geography of the South-East of England. The principal rivers, the Thames and Frome, each followed a syncline eastwards. On either side they received tributaries which rose upon the anticlines. The anticlines, however, have suffered severe denudation, and no longer maintain their dominance of elevation, but the rivers have kept their courses, and now cross in narrow defiles the chalk ridges which formed the foundations of the once continuous chalk arch. Admirable examples of such defiles are shown at Corfe Castle.

The curve of the strata in the Isle of Purbeck may be compared to the figure 2. The lower limb of the 2 represents the horizontal beds of the Hampshire basin, the middle limb shows the strata in a vertical or inverted position, while the upper limb illustrates the gentle curve by which they regain a more normal position. The strain, however, was too great to be relieved by folding alone, and overthrusting on a considerable scale came into play. The cliff-section of Ballard Down shows curving strata which belonged to the lower limb of the 2 resting upon the edges of vertical strata which belonged to the middle limb, a sharply-defined slide-plane (the Isle of Purbeck Fault) separating the two. Westwards from Lulworth Cove innumerable subsidiary thrust-planes can be detected in the chalk, and less easily in the Wealden and Purbeck beds. Everywhere along the line of the Isle of Purbeck Fault the chalk is greatly hardened, while the flints are broken, pulverised, and even drawn out into streaks of flint-powder. The Isle of Purbeck Fault dies out under Weymouth Bay, but is replaced a mile or two to the north by the parallel and still more energetic Ridgeway overthrust.

As regards the regions which it is proposed to visit, in the neighbourhood of Swanage the whole sequence from the base of upper chalk to the Portland Stone is open to examination, but time will not admit of more than a brief inspection of the Purbeck and Portland cliff-sections. The Upper Purbeck with Paludina limestones (or ' marble ' beds) and Unio beds form Peveril Point, and the Middle and Lower Purbeck beds are shown more or less continuously in Durlston Bay, a band composed of shells of *Ostrea distorta* (the ' Cinder Bed ') forming an easily recognised horizon. About 30 feet below the ' Cinder Bed ' lies the Mammal Bed, a thin, earthy layer which has yielded the remains of several genera of marsupials. Below this again are the Lower Purbeck limestones and marls, some with gypsum, casts of crystals of rock-salt and insect remains, others yielding a brackish water estuarine fauna. A double fault, with a downthrow south of 100 feet, near the zig-zag path, throws the Cinder

Bed from the top of the cliff to below the beach. The junction with the Portland Stone is not well shown in Durlston Bay.

The cliffs near Kimmeridge give a continuous section from the lowest Purbeck (on the top of St. Alban's Head) to a low horizon in the Kimmeridge Clay, more than 1000 feet of strata in all. From the head westwards they show a descending section in gently inclined strata, and at rather more than 500 feet below the top of the Kimmeridge Clay the 'Kimmeridge coal,' or 'brownstone,' emerges from below the beach. This highly bituminous layer is about 2 feet 10 inches thick, and has been worked in the neighbourhood from time immemorial, firstly for the manufacture of ornaments or utensils, latterly as a fuel and as a source of oil. During the war it attracted much attention as a possible source of oil and other products. Alum was also once manufactured here. In Hobarrow Bay the main anticlinal axis is reached, and thence westwards the same strata are crossed in ascending order, until the beetling crag formed by the Portland Stone comes down to the beach and stops further progress.

Lulworth Cove illustrates the effect of attacks by the surf upon nearly vertical strata, varying in their power of resistance. The Portland Stone has formed a natural break-water, which, however, has been breached in places. Stair Hole shows the first effects of a breach; the waves have worn holes through the stone, and are swilling the débris of the soft Upper Purbeck and Wealden strata through them. In Lulworth Cove the breakwater has been completely broken through, and a beautifully symmetrical natural harbour formed in the outcrops of the Purbeck, Wealden, and Gault formations. Everywhere the sea suffers a prolonged check on reaching the chalk.

The east side of Lulworth Cove shows all the formations below the chalk except the Lower Greensand, but much attenuated as compared with Swanage. Here an unconformity below the Gault, which becomes most pronounced at White Nothe, a few miles westwards, becomes manifest for the first time. The absence of Lower Greensand may be due in part to overstep by the Gault, and some of the uppermost Wealden beds also may be absent for the same reason. The section at White Nothe shows the Gault resting on steeply upturned Wealden, Purbeck, and Kimmeridge strata, and proves that there has been produced in pre-Gault times a set of flexures wholly independent of those of post-Oligocene age, though parallel to them. These earlier flexures are ignored by the rivers.

Mupe Bay, east of Lulworth Cove, affords a clear view of the passage of the Purbeck beds up into the Wealden, and of the abrupt but conformable junction of the Lower Purbeck and Portland Stone. Half a mile east of Lulworth Cove a ledge of the cliff provides an unrivalled opportunity of examining the lower part of the Purbeck beds, including the junction with the Portland Stone, the thin layer of carbonaceous, gravelly soil known as the dirt-bed, numerous stumps and prostrate trunks of coniferous trees silicified and enclosed in calcareous tufa, and the brecciated limestones associated with tufa, known as the 'broken beds.' Here the incoming of bands of tufa, among the sedimentary limestones, and the close association of such incoming with brecciation of the limestones, can be studied in detail. Westward from Lulworth Cove the cliffs illustrate the intense compression and supplementary overthrusting which all the formations have undergone in the neighbourhood of the Isle of Purbeck Fault.

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2. *The Chines of Bournemouth.* *By* Henry Bury, *F.G.S.*

The country round Bournemouth consists of an almost level plateau, intersected by numerous valleys, and some of the latter, running down to the sea, are of a precipitous character, and are distinguished under the name of 'Chines.' They are usually described as having started as small gullies in the face of the cliff and having worked back inland; but the evidence seems to be against this. Not only is there no sign of special activity at their heads, but each is found to consist of an older valley with a U-shaped section, and a newer one, shorter and narrower, shaped like a V. The older valleys probably joined the Frome-Solent River about 1–2 miles from the present shore-line; the newer ones owe their

smaller size to reduction in water supply, and their steepness to the rapid retreat of the shore-line under marine action. They are in fact growing shorter, and not longer, and the final obliteration of some of them may have helped to give rise to the belief that the cliffs themselves are growing steeper.

A Joint Discussion with Section H then took place on the Post-Tertiary Geology of the district, with special reference to flint implements, opened by the following Paper, which was illustrated by a collection of implements specially arranged by Mr. Scott :—

3. *The Post-Tertiary Deposits of the Bournemouth Area.*
By Reginald A. Smith.

The temporary exhibition of palæoliths from the Bournemouth district suggests further inquiry into the age and character of the beds in which they are found. Gravel is widely distributed over the high ground between the Stour and the coast at about 100 ft. O.D., and the implements are often found at the base of deep deposits in an unrolled condition, and therefore presumably *in situ*. The current view is that the gravels were laid down by a great river flowing eastward between the present coast-line and a southern bank connecting the Needles with the Isle of Purbeck; but in view of similar discoveries on St. Catherine's Hill (between the Avon and Stour and close to their junction), it seems likely that the Bournemouth gravels were originally continuous with those of the New Forest, and that the implements were imbedded in them before the present valleys of the Stour and Avon were deeply cut. Several implements have been found in high and low gravel-beds in the New Forest, and coast finds are abundant from Poole Harbour to Southampton Water. A section from Bramble Hill south-west to the coast is given in *Proc. Geol. Assoc.*, xxvi. (1915), 4, suggesting that the implement-bearing beds are part of a plateau deposit rather than the terrace-gravel of a Solent river.

In the afternoon a Sectional Excursion to Swanage took place.

THURSDAY, SEPTEMBER 11.

Joint Meeting with Section D.—See Section D, p. 211.

In the afternoon a Sectional Excursion to Corfe took place.

FRIDAY, SEPTEMBER 12.

The following Papers were read :—

1. *The Pre-Cambrian of Central Canada.*
By Willet G. Miller.

Ten years ago, at the Winnipeg meeting of the British Association, the author presented a paper dealing with the age relations of the pre-Cambrian rocks of Canada. Since then much field work has been done in connection with these rocks, not only in the province of Ontario, but to the eastward in Quebec and, to a lesser extent, to the westward in Manitoba and Saskatchewan. There has been great mining activity in the pre-Cambrian areas of Ontario, which has afforded special facilities for study to the geological staff of the Ontario Bureau of Mines. From time to time papers and reports have been

published as our knowledge has increased, and the age classification has been revised.[1] The following classification is now employed by the Ontario Bureau[2] :—

PRE-CAMBRIAN.

KEWEENAWAN	
Unconformity	
ANIMIKEAN	Under this heading are placed not only the rocks that have heretofore been called Animikie, but the so-called Huronian rocks of the 'classic' Lake Huron area, and the Cobalt and Ramsay Lake series. Minor unconformities occur within the Animikean.
Great unconformity	
(ALGOMAN granite and gneiss)	Laurentian of some authors, and the Lorrain granite of Cobalt, and the Killarney granite of Lake Huron, etc.
Igneous contact	
TIMISKAMIAN	In this group are placed sedimentary rocks of various localities that heretofore have been called Huronian, and the Sudbury series.
Great unconformity	There is no evidence that this unconformity is of lesser magnitude than that beneath the Animikean.
(LAURENTIAN granite and gneiss)	
Igneous contact	
LOGANIAN — Grenville (*Sedimentary*) / Keewatin (*Igneous*)	The Grenville limestones, with more or less greywacke quartzite and iron formation or jaspilyte at the base, were deposited on the Keewatin lavas.

It will be noted that the historic name 'Huronian' has been discarded. Much confusion has arisen through the employment of this name, especially with the prefixes Upper, Middle and Lower, in different senses. The term 'Lower Huronian,' for example, has been applied indiscriminately to certain rocks that lie below one of the greatest known unconformities—that between the Timiskamian and Animikean in the table—as well as to some of those above it. When making use of the term 'Huronian,' in order to secure clearness, it has been necessary to say in what sense it is employed, whether in that of the United States Geological Survey or in that of various writers on the subject.

Logan first studied the rocks, to which he afterwards gave the name 'Huronian,' on the shores of Lake Timiskaming. There are two series of conglomerates and other fragmental rocks here, separated by a great unconformity, which was discovered only when the geology of the Cobalt area was worked out. The lower series belongs to the Timiskamian of the table and the other to the Animikean.

The age relations of another historic series, the Grenville, have also been determined only during recent years. Most authors had suggested that the Grenville belonged to the so-called Huronian group of sediments, but it has

[1] *Ont. Bur. Mines*, vol. xix., part 2; *ibid.*, vol. xxii., part 2.
[2] *Journal of Geology*, vol. xxiii., No. 7.

proved to be the oldest sedimentary series. The Keewatin rocks, essentially schists and greenstones, represent, for the most part, submarine lava flows. On the surface of these flows were deposited the Grenville sediments. While the major part of the Grenville is later than the major part of the Keewatin, a minor part of one group is contemporaneous with a minor part of the other. It is remarkable that among the oldest series of Australia, India, Africa and other countries are rocks that resemble very closely the Keewatin of Canada, with its associated iron formation or jaspilyte.

Among most of the workers on the pre-Cambrian of North America there is now general agreement as to the age relations of the rocks, but different classifications and nomenclatures are employed. Most authors make a dual subdivision of the pre-Cambrian which seems to the author to be purely arbitrary and based on a misconception. There is no proof that the unconformity at the base of the Timiskamian is of less magnitude than that at the base of the Animikean, or *vice versâ*.

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2. *The Correlation of the Devonian Rocks of North Devon with those of other localities.* By Dr. John W. Evans, *F.R.S.*

The Dartmouth Slates of South Devon and Cornwall, which correspond, it would seem, to the Schistes d'Oignies of the Ardennes, are not seen in North Devon, but may be concealed by later rocks and be represented in South Wales and the Welsh Border by the Red Marls of the Lower Old Red Sandstone. It is possible that the Foreland Grits are a local facies of the upper portion of the Dartmouth Slates, just as the arenaceous Cosheston Group is a local development of the upper part of the Red Marls. Both the Foreland Grits and the Cosheston Group appear to have yielded the typical Old Red Sandstone plant *Psilophyton*.

[*Note*.—The author is not inclined to accept the view that the Foreland Grits are identical with the Hangmans Grits, which are repeated by faulting.]

The usual correlation of the Lynton Beds with the Meadfoots of South Devon seems well founded. The lower beds with Pteraspis may be compared with the Schistes de Saint Hubert of the Ardennes, with *Spirifer primævius* and *Pteraspic dunensis*, and the Schistes à *Pteraspis dunensis* in the Pas de Calais. The Senni Beds, which overlie the Red Marls on the north of the South Wales Coalfield, and contain Pteraspis and Cephalaspis, may be of the same age. The two strata as mentioned have not, up to the present, yielded any marine forms.

The Hangmans Grits represent a great thickness of arenaceous beds of the Old Red Sandstone type overlying the Lynton Beds. Little is known of the lower portion, but the upper beds include lacustrine or fluviatile beds, with plant remains which are probably referable to the Middle Devonian plant *Psilophyton*. These are succeeded by marine beds with several fossiliferous horizons, some of which have yielded *Stringocephalus*. The upper part at least of the Hangmans Grits must therefore be considered to be of Givetian age—that is to say, Upper-Middle Devonian, instead of Upper-Lower Devonian, according to the usual correlation. This view is supported by the discovery (after the reading of the paper) in the plant-bearing beds of a fish-plate referred by Dr. Smith Woodward to *Coccosteus*, a genus which is usually of Middle Old Red Sandstone and Middle Devonian age, though it has been found in the Upper Old Red Sandstone. The Staddon Grits of South Devon, on the other hand, which are usually considered to be the equivalent of the Hangmans Grits, cannot extend upwards much beyond the base of the Eifelian or Lower-Middle Devonian, as they are succeeded by calcareous slates with *Calceola sandalina*. The succession in the Middle Devonian of North Devon may be paralleled in the Boulonnais, where micaceous sandstones with plant remains are overlaid by marine beds with *Stringocephalus burtini*.

The Hangmans Grits are succeeded by the Combe Martin Beds, grits with occasional ferruginous crinoidal limestones, and these by the Ilfracombe Beds, shales and limestones with crinoids and corals. Except for an alleged occurrence of Stringocephalus which cannot now be verified, no distinctive forms

in fossils have been found either in the Combe Martin or Lower Ilfracombe Beds, and they may be either Upper-Middle Devonian (Givetian) or Lower-Upper Devonian (Frasnian). Unfortunately no goniatites have been found in the Devonian of North Devon, so that exact correlation is difficult. In higher portions of the Ilfracombe Beds *Spirifer verneuili* and *Rhynchonella* (*Wilsonia*) *cuboides* are found, which are sufficient to establish the Upper Devonian (presumably Frasnian) age of the rocks. The highest Ilfracombe Beds are less calcareous, and there seems no reason to doubt that they pass upwards conformably with the Merte Slates, the Upper Devonian age of which is completely established by the occurrence of *Spirifer verneuili* (var. *hamlingi*), and they may well represent the Schistes de Matagne, which form the highest beds of the Frasnian in the Ardennes. Rocks of the same age appear to be met with in the Boulonnais and in the boring in Tottenham Court Road in London. The Morte Slates become more arenaceous at the summit, and are probably succeeded conformably by the Pickwell Down Sandstones. The junction is usually faulted, but this is apt to be the case in strongly folded areas where successive beds differ considerably in physical characters, and the resistance they offer to the forces to which the rocks have been subjected. The Pickwell Down Sandstones have yielded the typical Upper Old Red Sandstone fish *Holoptychius* and *Bothriolepis*, and may be compared to the beds with the same forms reached by a boring at Southall, west of London, and to the Psammites de Condroz. They must be referred to the terrestrial or Old Red Sandstone type of the Famennian. The Baggy and Marwood Beds that overlie the Pickwell Down Sandstone and the lower portion of the succeeding Pilton Beds represent a marine facies of the Upper Famennian, as well as the Calcaire d'Etrœungt, which forms a passage to the Carboniferous in the Ardennes. The Upper Devonian of the Turnford boring in the Lea Valley, north-east of London, and the marine beds of the Upper Old Red Sandstone of South Wales and the Coomhola Grits in South Ireland are probably at about the same horizon as the Baggy and Marwood Beds and the base of the Piltons. The Upper Pilton Beds have now been shown to be of Carboniferous and not Devonian age, and to extend upwards and include the basement beds of the Zaphrentis zone.

It will be seen that North Devon is characterised by a repeated alternation of the terrestrial or Old Red Sandstone facies formed of materials laid down by rivers or in lakes or transported by the action of the wind and the marine facies of the Devonian. This alternation is even more remarkable here than that in the Eastern Baltic, with which all students of geology are familiar. There were three periods when the marine recession resulted in the deposition of the former, the first commencing in some areas towards the close of Silurian times. Each recurrence of the terrestrial facies is characterised by a completely different fauna and flora. There were also three periods of marine transgression, one about midway in the Lower Devonian, the second in the Givetian and Frasnian, and the third commencing near the close of the Famennian and reaching its maximum in the Carboniferous. In South Devon and Cornwall the conditions as a whole were more marine than in North Devon, and it was only during the deposition of the Dartmouth Slates in North Cornwall that entirely terrestrial (in this case fresh-water) conditions prevailed. In South Wales, on the other hand, Continental conditions were more prevalent than in North Devon, but a far more important difference between the north and south of the Bristol Channel lies in the complete omission, due either to non-deposition or erosion, of any representative of North Devon strata from at least low down in the Lynton Beds to the summit of the Morte Slates.

The variation of conditions of deposition which are so strongly marked in North Devon can be traced in most of the occurrences of Devonian rocks in other parts of the world, though they are nowhere else so striking and unambiguous. It is the deepening and transgression of the sea in Givetian and Frasnian times that is the most widely extended and most strongly marked of all these changes.

The Devonian period is not a natural division of the history of marine sedimentation characterised by a gradual deepening and subsequently a gradual shallowing of the ocean waters, but was determined solely by the interval between the last marine beds of the Silurian and the earliest marine beds of

the Carboniferous Limestone on the Welsh Border, where these strata were first studied in the early days of stratigraphical research. It was here that the limits of the Old Red Sandstone were originally fixed, and as a consequence also those of the contemporaneous rocks of marine origin elsewhere deposited which were a little later grouped together to form the Devonian.

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3. *Types of Faults in the Coal Measures (Yorkshire and Cumberland).* *By* Professor P. F. KENDALL *and* Dr. A. GILLIGAN.

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4. *The Erosion of Bournemouth Bay and the Age of its Cliffs.* *By* Dr. WILLIAM T. ORD, *F.G.S.*

The first step in the erosion of Bournemouth Bay was the breaking through by the sea of the range of chalk hills which were formerly continuous from the Needles to Ballard Down. There is evidence that the gap occurred at a point due south of Bournemouth pier. It is thought that the Swanage River would here have flowed through the hills to join the Solent River (which then crossed, what is now the bay, from Poole Harbour to the Solent), following the examples of the Corfe streams, and the Yar in the Isle of Wight, each of which cuts north through the chalk. The break through must have taken a long period, though once accomplished the friable Tertiary beds were rapidly washed out of the bay. During Miocene times the Hampshire Basin was formed by upheaval of the two southernmost chalk anticlines, as were the North and South Downs and Chiltern Hills. The sea was then far to the south, and busy eroding the Purbeck and Portland barrier, which still shows in fragments along the Dorset coast. The Frome-Solent River flowed across what is now Bournemouth Bay, through the Solent, to enter the sea at Spithead. Its tributaries were the Bourne, Stour, and Avon, and others from the New Forest. During the Pliocene subsidence the sea advanced to the southern flanks of the chalk anticline between Purbeck and the Island. Then occurred the Raised Beach Period, when the land was stationary at 30 ft. above O.D. for a time sufficient to form the beaches, remains of which are found at Portland, Torquay, Cornwall, and the Bristol Channel. It was probably at this time that the sea first gained access to Bournemouth Bay through the gap cut by the Swanage River. Rapid erosion occurred on both sides, but chiefly eastward towards the Needles. Admiralty charts show a shallow bank which indicates the base of the destroyed chalk ridge. The sea destroyed the old drainage system, and received the Rivers Frome, Bourne, Avon, and Stour directly. As it advanced it formed a low line of cliffs around the bay some distance south of the present cliffs. This period closed by a re-elevation of the land, when the sea receded to the south, leaving Bournemouth Bay once more dry; this probably continued during the Glacial Period which immediately followed. There is nothing to show what changes occurred during the Glacial Period, but we know that, towards the end, vast floods from melting ice washed flint gravel from the high ground northward and deposited it in sheets (containing palæolithic implements) as the Plateau Gravels that cover our cliffs to-day. The Neolithic Period was ushered in, according to Mr. Clement Reid, by a re-elevation of some 80 feet. Since then a gradual subsidence has set in, and the sea has again invaded Bournemouth Bay. Then grew the forests which have gradually become submerged. Remains of these, far to the south of the present pier, were observed by Sir Charles Lyell in 1825, and forty years previously by Mr. Fisher. A century ago Sir John Evans records that a stretch of swampy ground separated the foot of the cliffs from the sea. It seems then that only within the last century has the sea reached the foot of the old line of cliffs, which were formed in pre-Glacial times. As the talus which protected them was washed away and the new and old cliffs became one, erosion would be more rapid, and the cliff face more perpendicular. There is plenty of evidence to confirm this in recent measurements by the Borough Engineer, which give accurately the present rate of erosion of the cliffs at various points.

The Discovery of Diamonds in the Gold Coast, British West Africa. By A. E. Kitson, *C.B.E., F.G.S. (Director, Geological Survey, Gold Coast).*[1]

The site of the discovery of diamonds, which I made early this year, is at Abomoso, in the district of Akim Abuakwa, about sixty-five miles to the north-west of Accra, the capital of the Gold Coast. The rocks of the district consist of a thick series of phyllites, altered mudstones, sandstones, grits, and conglomerate, with interbedded altered dolerites and tuffs. They have a general strike of about N.E.-S.W., and are moderately folded. On their north-western and south-eastern sides, and in their south-westward extension, they are intruded in many places and greatly metamorphosed by granites and pegmatites, and to a less extent by diorite.

The diamonds occur in detrital gravels resting on the top and side of a low ridge, and in the beds of shallow streams. These gravels consist very largely of quartz, principally of opaque, semi-opaque, and transparent varieties. The associated minerals are chiefly sisolite, white and brown micas, zircon, pyrite, magnetite, ilmenite and gold, with rarer fragments of rutile, black tourmaline, red garnet, chalcedony, brown corundum, kyanite, and sphene. In general character this gravel has unquestionably the appearance of having been derived from granitoid rocks.

Small diamonds have been found also in the beds of four streams up to fourteen miles to the north-west, and in two streams to five miles to the north-east of this place. In addition, one diamond has been found in the quartz pebble gravels of the upper terrace of the Birrim River.

At the site of the original discovery the bulk of the gravel is distinctly angular in character, but has associated bands of rounded quartz sand, and a few water-worn pebbles of quartz.

The diamantiferous gravels of the streams to the north-west consist largely of quartz, felspar, mica, and fragments of pegmatite, but have a good deal more chert and chalcedony than those near Abomoso, though still in small proportions.

The pebbly gravels of the high terraces of the Birrim River, and of the beds of the streams to the north-east, which are mainly rounded pebbles of quartz, altered sediments, and volcanic rocks, give concentrates consisting largely of chloritic minerals, ilmenite, magnetite, and quartz.

Some 620 diamonds have been found merely by panning during operations to test the character, extent, and distribution of the diamantiferous material. All the stones are small, the average being about thirty-two to the metric carat (3.174 grs. Troy). The largest, a clear, colourless, octahedron, weighs a little over one-sixth of a carat. Many of the diamonds are beautiful crystals, colourless and transparent, the commonest forms being the octahedron and the rhombic dodecahedron, though there are numbers of tetrahedral forms as well. Cleavage plates of octahedra occur in fair numbers. Several of these show that the parent crystals were much larger than the largest stone hitherto found here. Some of the crystals show curved faces; many others are chipped; and there are numerous fragments. Many of the stones are clear and colourless; others are of pale yellow, blue, green, grey, and brown tints, principally the last.

The largest stone is valued at about £1. The largest grade of colourless stones, weighing about eleven to the carat, are valued at 80*s.* to 100*s.* per carat; the medium grade, about twenty-two to the carat, at 60*s.* to 70*s.* per carat; and the smallest grade, about sixty-four to the carat, at 25*s.* to 40*s.* per carat. The coloured stones of the same groups may be taken at about 40*s.*, 30*s.*, and 15*s.* per carat respectively.

In the Abomo Su area the bed-rock in some places proved to be phyllites or sandstones; in others, a decomposed altered basic tuff or lava, full of chloritic minerals. A good deal of this material was panned, but no diamonds were found in it, though the overlying detrital material in every case yielded diamonds.

[1] See Report published by Government of the Gold Coast.

The general character of the diamantiferous gravel, and the concentrates therefrom, occurring at the site of the first discovery, suggests a derivation from a granite-pegmatite area, but the angular quartz and the ragged gold are undoubtedly of local origin. Since veins of quartz occur plentifully in the underlying rocks, this angular material has most probably been derived therefrom. The diamond found at a depth of about eight feet in the Birrim terrace gravels, and those found in the streams to the north-west and the north-east, show clearly that some at least of the stones, though detrital, are not of local derivation.

The matrix of the diamonds has not yet been determined. The stones may have been derived from volcanic pipes of kimberlite, as in South Africa, or of dolerite, as in New South Wales, intruded into or through the Birrim series in Birrimian (pre-Cambrian?) or post-Birrimian times; or from conglomerates of those times; or they may have been formed by the action of pegmatite dykes or granite intrusions on carbonaceous rocks of the Birrim series. Whatever may be the origin of the stones, the evidence so far obtained suggests that they have not been derived directly from pipes, but that they are detrital.

In the afternoon a Sectional Excursion to Barton and Hordle Cliff took place.

SATURDAY, SEPTEMBER 13.

Sectional Excursion to Lulworth.

SUNDAY, SEPTEMBER 14.

Sectional Excursion to Kimmeridge.

Section D.—ZOOLOGY.

President of the Section: F. A. Dixey, M.A. M.D. F.R.S.

TUESDAY, SEPTEMBER 9.

The President delivered the following Address:—

One of the results of the great war now happily at an end has been its effect upon science. On the one hand it has checked the progress of scientific investigation; it has done much to destroy international co-operation and sympathy; it has removed from our ranks, temporarily or permanently, many admirable workers. On the other hand it has acted as a great stimulus in many departments of scientific inquiry, and it has given the general public an interest in many scientific questions which have hitherto met with little recognition or encouragement from the people at large. It was perhaps inevitable, but at the same time, as I venture to think, rather to be deplored, that that interest has tended to concentrate itself upon applied more than upon abstract science; that it has been concerned chiefly with the employment of natural knowledge in devising and perfecting new methods of destruction. Terrible as is the power which the present-day engines of warfare have attained, it may be reasonable to hope that some compensation for the mischief and suffering which they have caused may eventually be found in peaceful directions; that the submarine, the air-craft, and even the high explosive may cease to be a terror to civilisation, and in spite of their past history may after all become agents in the advancement of the general welfare:

Hoc paces habuere bonae, ventique secundi,

will, let us hope, be a legitimate reflection in later times. But for the true scientific worker, I think I may safely assert, the primary object of his studies is the attainment of knowledge for its own sake: applications of such knowledge may be trusted to follow; some beneficial, some perhaps the reverse. Still, whether they do or do not so follow is less a concern of the scientific man than whether his labours have resulted in a fresh advance into the realms of the unknown. I confess to some sympathy with the feeling which is said to be expressed in the regular toast of a certain scientific gathering:—'Pure mathematics, and may they never be of any use to anybody.'

For genuine enthusiasm in the cause of science for its own sake, I think that we zoologists may claim a good record. We are by no means unmindful of the great benefits to humanity which have taken their rise more or less directly from zoological science. I need do no more than mention the services to medicine, great at the present and destined to be greater still in the future, that are being rendered by the protozoologist and the entomologist. We may look forward also to results of the highest practical importance from the investigations into the laws of heredity in which we are engaged with the co-operation of our allies the botanists. But what we are entitled to protest against is the temper of mind which values science only for the material benefits that may be got from it; and what above all we should like to see is a greater respect on the part of the public for science purely as science, a higher appreciation of the

labours of scientific men, and a greater readiness, in matters where science touches on the common affairs of life, to be guided by the accumulated knowledge and experience of those who have made such matters the subject of constant and devoted study. If the war leads to any repair of the general deficiency in these respects, it will to that extent have conferred a benefit on the community.

Regarding, as I do, my present position in this Section as a great honour and privilege, especially in view of this being the first meeting of the British Association to be held after the war, I hope I may be allowed a few preliminary remarks of a somewhat autobiographical character. As far back as I can remember, zoology has been a passion with me. I was brought up in a non-zoological environment, and for the first few years of my life my only knowledge of the subject was gained from an odd volume of Chambers's 'Information for the People.' But on being asked by a visitor what I intended to do with myself when I grew up, I can distinctly remember answering, with the confident assurance of seven or eight, 'Zoology suits me best'—pronouncing the word, which I had only seen and never heard, as *zoology*. By the time I went to school, my opportunities had increased, but I soon found myself engaged in the classical and mathematical routine from which in those days there was little chance of escape. In due course I went to the University with a classical scholarship, which necessitated for the time an even more rigid exclusion of scientific aspirations than before. I mention this because I wish to pay a tribute of gratitude to the College authorities of that day, to whose wise policy I owe it that I was eventually able to fulfil in some measure my desire for natural, and especially biological, knowledge. After two years of more or less successful application to the literary studies of the University, I petitioned to be allowed to read for the final school in natural science. The petition was granted; my scholarship was not taken away, and was even prolonged to the end of my fifth year. This I think was an enlightened measure, remarkable for the time, more than forty years ago, when it was adopted. I only hope that we have not in this respect fallen back from the standard of our predecessors. The avidity with which I took up the study of elementary chemistry and physics, and the enthusiasm with which I started on comparative anatomy under the auspices of George Rolleston are among the most pleasant recollections of my youth. But from the force of circumstances, though always at heart a zoologist, I have never been in a position to give myself unreservedly to that department of biology; and even now, in what I must call my old age, I fear I cannot regard myself as much more than a zoological amateur. My working hours are largely taken up with serving tables.

What moral do I draw from this brief recital? Not by any means that I should have been allowed to escape a grounding in the elements of a literary education, though I think it quite possible that the past, and even the present methods of school instruction are not ideally the best. My experience has led me to conclude that much of the time spent over the minutiae of Greek and Latin grammar might, in the case of the average boy, be better employed. But I do not agree that a moderate knowledge of the classics, well taught by a sensible master, is useless from any reasonable point of view. To those of my hearers who appreciate Kipling, I would call to mind the vividly truthful sketch of school life called 'Regulus.' Let them reflect how the wonderful workmanship of the inspired and inspiring Ode of Horace, round which the sketch is written, must have sunk into the mind of the apparently careless and exasperating 'Beetle,' the 'egregious Beetle' as King calls him, to bear such marvellous fruit in after years. Beetle, as we all know, is no professional scholar, no classical pedant, but a man of the world who has not forgotten his Horace, and upon whose extraordinary literary skill those early school-tasks must have had, whether consciously or not, a dominating influence. How else could he have written 'Regulus'? 'You see,' says King, 'that some of it sticks.' So it does, if it is only given a fair chance; and in the skirmish between King the classical and Hartopp the science master, both right up to a point and both wrong beyond it, I give on the whole the palm to King. To revert to my own case. I do not regret a word of either the Latin or the Greek that I was obliged to read, nor even the inkling of the niceties of scholarship to which I got, I hope, a fair introduction. But I do think that I might have been allowed to start on scientific work at an earlier period, and that a good

deal of the time spent, say, on Greek and Latin prose and verse writing, might in my case have been well spared for other objects.

To generalise what I have been saying. Start teaching your boy or girl on a good wide basis. Nothing is better for this than the old school subjects of classics, history and mathematics, with the addition of natural science. In course of time a bent will declare itself. Encourage this, even at the expense of other studies desirable in themselves. But do not allow any one subject, however congenial, to usurp the place of a grounding in those matters which are proper to a general education. The time for specialising will come; and when it has arrived do all you can to remove obstacles, pecuniary and other. Do not hamper your historian with chemistry or your zoologist with the differential calculus. If they have a taste for these things by way of diversion or recreation, well and good. But let their action be voluntary.

This, however, is not a fitting occasion for propounding my views on the question of education, and it is time to turn to the immediate object of my address. And here I think I cannot do better than to bring before your notice certain facts which have a bearing on the subject of insect mimicry; a subject which for many years past has engaged much of my attention. The facts on all hands are allowed to be remarkable. As to their interpretation there is much diversity of opinion; and indeed, until complete data are forthcoming, this could hardly be otherwise.

The Geographical Factor in Mimicry.

In the first place let us glance at a certain assemblage of butterflies that inhabits New Guinea with some of the adjacent islands. These butterflies, though belonging to different subfamilies, present a resemblance to each other which is too strong to be accidental. Three of them belong to the Pierines, the group which includes the common white butterflies of this country; the fourth is a Nymphaline, not widely removed from our well-known tortoiseshells, red admiral and peacock. The resemblance on the upper surface between two of the three Pierines is not especially noteworthy, inasmuch as they present in common the ordinary Pierine appearance of a white or nearly white ground colour with a dark border somewhat broadened at the apex. But this, an everyday feature in the Pierines, is almost unknown in the very large subfamily to which our present Nymphaline belongs. Still, though sufficiently remarkable to arrest the attention of anyone familiar with these groups, the Pierine-like aspect of the upper surface of this Nymphaline, which is known as *Mynes doryca*, would not by itself have seemed to call for any special explanation. The resemblance would pass as merely an interesting coincidence. But the under surface of the three Pierines, known respectively as *Huphina abnormis*, *Delias ornytion* and *Delias irma*, presents a striking combination of colour very unusual in their own group; and this peculiar character of the under surface is shared by the Nymphaline *Mynes doryca*. The 'long arm of coincidence' could scarcely reach as far as this. Whatever might be said about the likeness seen from above, that the wings beneath should show virtually the same unusual pattern in the *Mynes* as in the Pierines seems to call for some explanation other than an appeal to chance or accident. Moreover, with regard to the Pierines themselves, the two members of the genus *Delias* are of course fairly closely related; but the *Huphina* belongs to an entirely distinct genus, separated from *Delias* by many important structural differences. The two species of *Delias* perhaps depart less widely in aspect from their nearest congeners than does either the *Huphina* or the *Mynes*. The under surface of the *Huphina* is unexampled in its genus, but the upper surface is quite ordinary. The *Mynes*, as we have seen, stands alone among its nearest relatives not only in the character of its under surface, but also in the Pierine-like character of its wings above.

We will now turn to another assemblage, which presents us with the same problem from a somewhat different point of view. In south-eastern Asia, with certain of the adjacent islands, is found a genus of large butterflies, called by Wallace *Prioneris* from the saw-like front margin of the forewing in the male. More than fifty years ago it was remarked by Wallace that the species of *Prioneris*

in several cases seem to mimic those of the genus *Delias*, and that 'in all cases the pairs which resemble each other inhabit the same district, and very often are known to come from the same locality.' The parallelism is even stronger than was stated by Wallace, for there is not a single known member of the genus *Prioneris* which does not resemble a species of *Delias*, so that *Prioneris* cannot really be said to have an aspect of its own. *Prioneris clemanthe* and *Delias agostina* form a pair inhabiting the Himalayas, Burma and Further India. In the same region occur *Prioneris thestylis* and *Delias belladonna*, the striking similarity of which species, especially on the underside and in the female, drew the special attention of Mr. Wallace. A still more remarkable instance is that of *Prioneris sita* of southern India and Ceylon, the likeness of which to the common Indian *Delias eucharis* is spoken of by Wallace as 'perfect'; while Fruhstorfer, a hostile witness, testifies to the fact that the *Prioneris* always flies in company with the *Delias*, and rests just like the latter with closed wings on the red flowers of the Lantana. *Prioneris hypsipyle* of Sumatra and *P. autothisbe* of Java are like *Delias egialea* and *D. crithoe* of the same two islands. Here again Fruhstorfer says of *Prioneris autothisbe*, that it visits the flowers of the Cinchona, 'always in company with the similarly coloured *Delias crithoe*.' Wallace remarked on the close similarity between *Prioneris cornelia* of Borneo and *Delias singhapura* of the Malay Peninsula; in this case, it will be noted, the localities though not far distant from each other, are not identical. But a *Delias* form which was unknown at the date of Wallace's paper has since been found in Borneo, and this latter butterfly, known as *D. indistincta*, is even more exactly copied by *P. cornelia* than is the *Delias* which first drew Wallace's attention. *Prioneris vollenhovii* of Borneo is a kind of compromise between *Delias indistincta* and, on the underside, *D. pandemia* of the same island; and it may be added that another Bornean Pierine, *Huphina pactolica*, is a good copy of *Delias indistincta*, therefore resembling also the Bornean *Prioneris cornelia* and *P. vollenhovii*.

The memoir, published in 1867, in which Wallace remarked on the parallelism between *Prioneris* and *Delias*, contains a noteworthy prediction by the same author. Speaking of *Pieris* (now called *Huphina*) *laeta* of Timor he says that it 'departs so much from the style of colouring of its allies and approaches so nearly to that of *Thyca* (*Delias*) *belisama* of Java, that I should almost look for an ally of the last species to be discovered in Timor to serve as its pattern.' Thirty-four years after the expression of this anticipation, Mr. Doherty discovered in Timor an ally of *Delias belisama* which at once suggests itself as the model from which the peculiar and brilliant colouring of *Huphina laeta* has been derived. Fruhstorfer, who is by no means friendly to the theory of mimicry, says of this *Delias*, which was named *splendida* by Lord Rothschild, that beneath it is 'deceptively like *Huphina laeta*.' But here comes in a curious point. The black forewing with its yellow apex and the orange-yellow hindwing with its scarlet black-bordered costal streak are present on the underside of both the *Delias* and the *Huphina*; but the latter butterfly possesses in addition to these features a row of scarlet marginal spots on the hindwing which are not to be found on the *Delias*. In spite of this discrepancy, the likeness is sufficiently striking. But from the same island of Timor, Doherty sent home another *Delias* which besides resembling *D. splendida*, possesses a row of scarlet patches in the corresponding situation to those of *H. laeta*. In this latter *Delias*, however, named *dohertyi* by Lord Rothschild after its discoverer, the brilliant scarlet costal streak is completely absent. The *Huphina*, therefore, is more like either species of *Delias* than they are like each other, forming, as it were, a link between them. So that, adopting Professor Poulton's terminology, we may say that, if this is a case of mimicry, one form may possess at the same time the aposemes belonging to two distinct models. I will not now stop to discuss the bearing of this case on current theories, but will only remark that, granting mimicry, the whole assemblage, *D. splendida*, *H. laeta*, *D. dohertyi*, may be expected to gain advantage from the blending action of the intermediate *H. laeta*. This I think would happen whether *laeta* is a 'Batesian' or 'Müllerian' mimic, but the gain to the association in the latter case is certainly the more obvious.

This state of things would be sufficiently curious if it stood by itself. But it

does not stand by itself. In Lombok, Sumbawa and Flores there occurs another member of the peculiar group of *Huphina* to which *H. laeta* belongs. This butterfly, known as *H. temena*, resembles *H. laeta* in many respects; possessing on the underside of the hindwing a scarlet costal streak and a row of scarlet marginal spots like those of that insect. The forewing, however, differs from that of *H. laeta* in having its ground-colour not uniformly black, but divided between a dark shading to the veins, a dark submarginal band, and series of pale streaks and patches in the interspaces between the veins. The question at once suggests itself: Is there a relation between *H. temena* and one or more species of *Delias* corresponding to that between *H. laeta* and *D. splendida* and *dohertyi*? The answer to this question is in the affirmative. *Delias oraia*, together with *Delias sumbawana*, both species inhabiting the same three islands as *H. temena*, form with it an assemblage quite comparable with the former triad from Timor. Further, the points in which *H. temena* differs from *H. laeta* have their counterpart in the distinctions between *D. oraia* and *D. splendida* on the one hand, and *D. sumbawana* and *D. dohertyi* on the other. These points are chiefly, in the *temena* assemblage, the less definitely black-bordered costal streak, the more strongly-marked black bordering to the submarginal scarlet spots, and the diversely-coloured as compared with the uniformly black forewing of the Timor insects.

Again, in the island of Bali, *Huphina tamar* would seem to combine certain features of two species of *Delias* in a similar manner to the cases of *laeta* and *temena* just considered. The underside as a whole is reminiscent of *D. periboea*, a member, like *D. dohertyi* and *D. sumbawana*, of the *eucharis* or *hyparete* group of the genus; while the red costal streak suggests the influence of a representative in Bali of the *belisama* group, like *D. splendida* and *D. oraia* in the other islands.

Finally, in the island of Sumba we have another member of this remarkable group of *Huphinas*. *Huphina julia*, the butterfly referred to, so closely resembles *Delias fasciata* of the same island, that even the sceptical Fruhstorfer is constrained to speak of it as a 'faithful copy' of that insect. But here once more it is noticeable that one of the most conspicuous features of the *Huphina* is absent from the *Delias*. This time it is not, as in the case of *D. splendida*, the submarginal row of scarlet spots on the underside of the hindwing, but it is the scarlet costal streak that is wanting. *Huphina julia* was discovered by Mr. Doherty in the year 1887, and described in 1891. It is interesting, in the light of what is now known of the butterfly fauna of the Lesser Sunda islands, to read what Doherty has to say about the mimicry question in relation to the *Delias* and *Huphina* forms that have just been mentioned. Speaking of *H. julia*, he says, 'If it stood alone, I should certainly suppose it to be a mimic of some form of *Delias hyparete* yet undiscovered in the island. But both *H. laeta* and *H. temena* require to be accounted for in the same way, and while it is possible that some Timorese *Delias* may resemble *H. laeta*, I feel sure that *H. temena* can have no such original. It must then be assumed that this group is less pressed by its enemies in the Timorian Islands, and has therefore been able to acquire more brilliant colours than its allies.' So far Doherty.

Whatever may be the value of this last hypothesis, we have just seen that the supposed facts on which it rests are non-existent, for (1) the 'form of *Delias hyparete* as yet undiscovered' has actually turned up in the person of *D. fasciata*; (2) it is not only possible, but actually the case that 'some Timorese *Delias* may resemble *H. laeta*'; (3) Mr. Doherty 'feels sure that *H. temena* can have no such original,' but *Delias oraia* and *Delias sumbawana* have just the same relation to *Huphina temena* as *D. splendida* and *D. dohertyi* to *H. laeta*. In view of these facts it may be not rash to suppose that the apparent absence of a model for the red costal streak of *H. julia* may hereafter be accounted for.

Of the three instances of possible mimetic association which have now been mentioned, I think that only one—*viz.*, the first, has previously been treated in detail. The numbers of cases more or less similar to these three might be very largely extended, but for our present purpose it will be sufficient to confine our attention to those already given. It is probable that to some minds the facts adduced are simply curious coincidences, needing no explanation; but it can hardly be wrong to suppose that to most students of Nature the observed phenomena do call for some attempt at interpretation; and on a review of the

evidence it seems clear that the geographical element must enter largely into any explanation that may be offered. On the whole, it is certainly the case that the forms which are supposed to be related by mimicry do inhabit the same localities; the continental *Prioneris*, for example, is like the continental *Delias*, and the island *Prioneris* recalls the island, not the continental, *Delias*. Moreover, we find the differences between the *Delias* of Timor, of Sumbawa and Sumba, reflected in the associated *Huphinas* of the same islands. If it be granted that the geographical element is a factor, it is natural to inquire how it works.

It is no doubt true that external geographical conditions are occasionally capable of producing, whether directly or indirectly, a community of aspect in the animals or plants exposed to their influence. The prevalence of a sandy coloration in the mammals and birds of a desert, and of whiteness in the inhabitants of the arctic snow-fields, the spiny character so often assumed by the plants of arid regions, and the general dwarfing of the vegetation that grows close to the sea, may be given in illustration. At first sight these phenomena may seem to be of the nature of direct effects of the environment; quite possibly some of them are so, but I think that few observers would deny that they are at least largely adaptive, being used for purposes of aggression or defence. Still, even if we allow the direct effect of the environment, as perhaps we may do especially in the case of the plants, can we frame any hypothesis of the action of geographical conditions which shall lead directly to the assumption of a common pattern in the case of the three or four butterflies from New Guinea? I confess that I am quite unable to do so. If the climate, or the soil, or any other geographical condition in New Guinea is capable of directly inducing so remarkable a combination of colour as we see in these Pierines and Nymphaline, why does it not affect other organisms in a similar way? Why do not other Pierines, for instance, closely related to *ornytion* and *abnormis*, share in the same coloration? And considering the characteristic aspect of the underside, which is supposed to be called into being by some unexplained condition peculiar to New Guinea, we may well ask, Why should its most conspicuous features belong in the one case to the forewing and in the other to the hindwing, and *vice versâ*, the general effect being the same?

Fruhstorfer, we may note, does not feel these difficulties. 'Many Pierids,' he says, 'present typical examples of that resemblance to other butterflies which has been named Mimicry. The origin of this resemblance, however, is now explained by the supposition that the mimics were modified by the same (as yet unknown) influences under which the colouring of the models, mostly Danaids, developed.' I think it will be generally agreed that this reference to 'unknown influences' is no explanation at all.

It is necessary to take into account the fact that the resemblances of which we are speaking are independent of structural differences, being, in fact, merely superficial. This is a point which is capable of much wider demonstration than I am giving it to-day. But even from the instances now before us I think there cannot be much difficulty in coming to the conclusion that the resemblances are an appeal to vision. They are meant to be *seen*, though by whom and for what purpose may be open to question. Speculations as to recognition and sexual attraction may, I think, in these cases be put out of court; but there remains the theory of warning colours assumed in reference to the attacks of vertebrate enemies. From the fact that the most striking and most conspicuous of these common aposemes or danger-signals belong to the under surface—that is to say, the part chiefly exposed to view during rest—it may be inferred that the enemies to be guarded against are mainly those that attack butterflies not on the wing, but when settled in repose. Both birds and monkeys are known to feed on butterflies, and there is a good deal of evidence as to their preference for one kind of food over another. I will not stop to give details, but anyone who wishes to study the evidence may be referred especially to the Memoirs of Dr. G. A. K. Marshall, Mr. C. F. M. Swynnerton, and Captain G. D. H. Carpenter.

If the warning-colour interpretation of these resemblances be the true one, we see at once why they are so largely independent of structure and affinity. Being meant to catch the eye, they ride rough-shod, so to speak, over incon-

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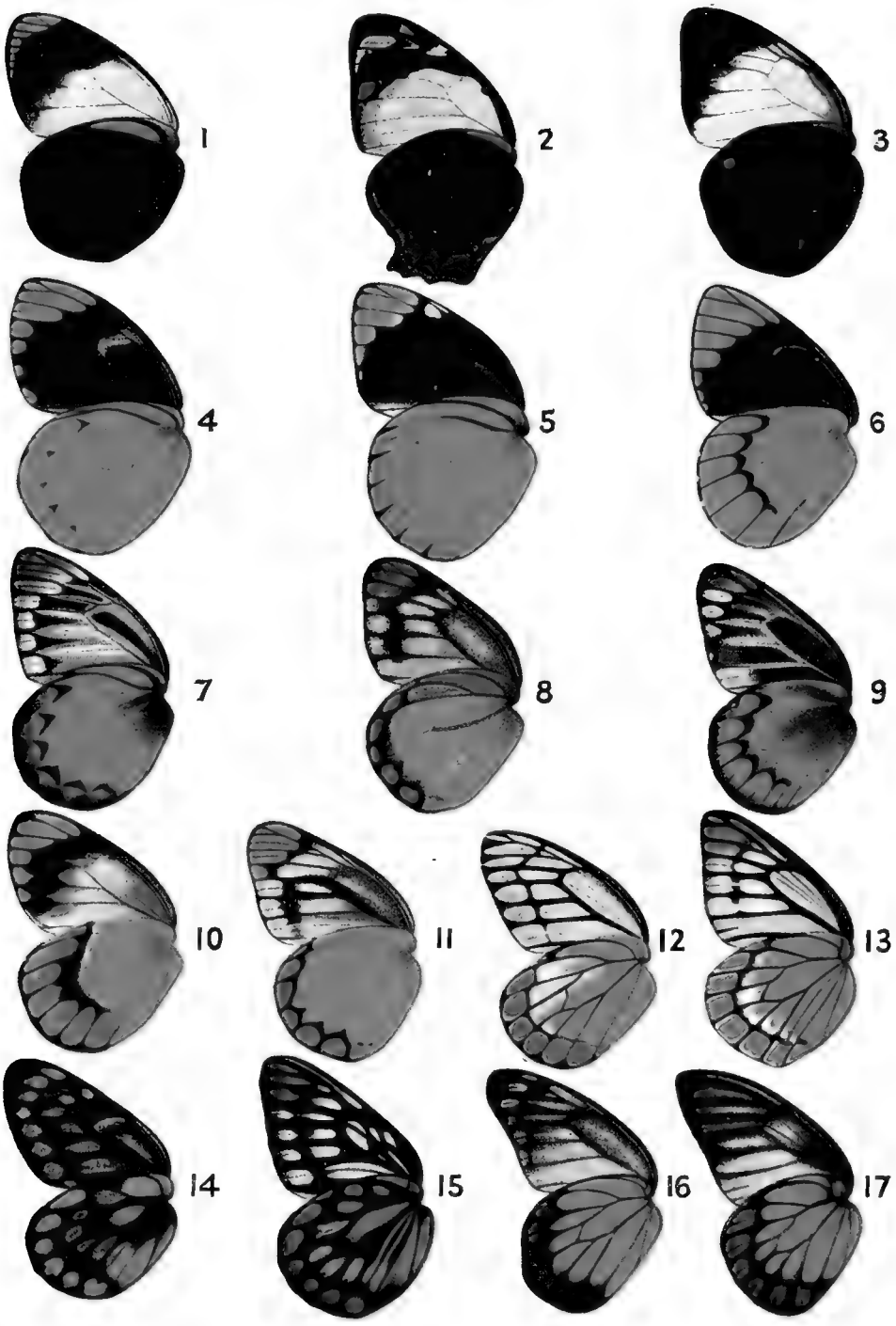

Illustrating 'The Geographical Factor in Mimicry.'

[*Between pages* 204 *and* 205.

EXPLANATION OF PLATE.

Fig.		
1.	Delias ornytion *Godm. & Salv.*	New Guinea
2.	Mynes doryca *Butl.*	,,
3.	Huphina abnormis *Wallace*	,,
4.	Delias splendida *Roths.*	Timor
5.	Huphina laeta *Hew.*	,,
6.	Delias dohertyi *Roths.*	,,
7.	Delias oraia *Dohrt.*	Lombok, Sumbawa, Flores
8.	Huphina temena *Hew.*	,,
9.	Delias sumbawana *Roths.*	,,
10.	Delias fasciata *Roths.*	Sumba
11.	Huphina julia *Dohrt.*	,,
12.	Delias eucharis *Drury*	India, Ceylon
13.	Prioneris sita *Feld.*	S. India, Ceylon
14.	Delias belladonna *Fabr.*	N. India
15.	Prioneris thestylis *Doubl.*	,,
16.	Delias indistincta *Fruhst.*	Borneo
17.	Prioneris cornelia *Vollenh.*	,,

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spicuous features, such as venation; nor do they respect more than the nature of things obliges them to do, the ties of blood-relationship. Then, again, it is obvious why they occur in the same and not widely different localities; in some instances, as we have seen, their bearers actually flying in company and frequenting the same flowers; for the common aspect, supposing it to be in any sense protective, would only take effect when the sharers in it were exposed to the attacks of the same body of enemies; that is to say, when they inhabited the same locality. And this would be equally true, whether the warning colours are shared between distasteful forms, or whether they are deceptively adopted by forms unprotected by inedibility;—whether, in Professor Poulton's terms, they are synaposematic or pseudaposematic. I do not enlarge upon this part of the question, or upon the theories which are known under the names of Bates and Müller respectively, because these theories have been fully dealt with elsewhere, and I think I may assume that they are familiar to the greater part of my hearers. But that mistaken ideas as to what is really meant by protection and mimicry still prevail in some quarters is evident from certain remarks of Fruhstorfer in dealing with the genus *Prioneris* which we have just been discussing. 'Wallace,' he says, 'regards the "rarer" *Prioneris* as a mimetic form of the "commoner" *Delias*. But I cannot accept his view, since mimicry among the in all respects harmless Pierids appears no sort of protection, and properly speaking the smooth-margined *Delias* should rather copy the armed *Prioneris* if there is assumed to be mimicry at all.' If anyone has no better knowledge than this of what is meant by the theory of mimicry, it is not wonderful that he should consider the subject unworthy of serious attention.

The warning-colour theory, then, gives a rational explanation both of the superficial character of the resemblances and of the geographical factor in their occurrence. But it obviously involves the reality of natural selection; and it is here that some are disposed to part company with the upholders of the theory. I have already referred to the fact that much positive evidence now exists both that butterflies are eaten and that preferences on the part of their enemies exist between one kind and another. I will only remark in passing that the objector on this score sometimes adopts an attitude which is scarcely reasonable, and which perhaps on that very account is somewhat hard to combat. The kind of objector that I mean begins by saying that the destruction of butterflies by birds and other enemies is not sufficient to give play for the operation of selection. You beg his pardon, and produce evidence of considerable butterfly destruction. To which he replies, 'O, they *are* eaten, are they? I thought you said they were protected.' This is a good dilemma, but the dilemma is notoriously an unconvincing form of argument. If a reply be called for it may be given like this: 'Butterflies are either preyed upon or they are not. If they are, an opening is given for selection; if they are not, it shows the existence of some form of protection.' The essence of the matter is that both the likes and dislikes of insectivorous animals, and the means of protection enjoyed by their prey, are not absolute but relative. A bird that will reject an insect under some circumstances will capture it under some others; it will, for instance, avoid insect 'A' if it can get insect 'B,' but will feed on 'A' if nothing else is to be had; and it is probable that hardly any insect is entirely proof against the attack of every kind of enemy. The relative nature of protection is readily admitted when the question is not one of mimicry or of warning colours, but of protective resemblance to inanimate objects. All degrees of disguise, from the rudimentary to the almost perfect, are employed; the lower degrees are allowed to be of some service, and on the other hand a disguise that is almost completely deceptive may at times be penetrated. This consideration applies also to the objection that the first beginnings of mimetic assimilation can have no selective value. If the rough resemblance to an inanimate object affords some amount of protection, though that amount may be relatively small, why should not the same apply to the first suggestion on the part of a mimic of an approach to the aposeme or warning colour of its model? The position that neither kind of assimilation is of service is intelligible, though not common; but there is no reason why benefit should be affirmed in the one case and denied in the other. There are further considerations which tend to deprive this latter criticism of force; the fact, for instance, that a resemblance to one

form may serve as a stepping-stone for a likeness to another; or, again, the existence of clusters, as they may be called, of forms varying in affinity, but embodying a transition by easy stages from one extreme to another. In a case of this sort the objection that may be felt as to two terms in the series arbitrarily or accidentally picked out is seen to be groundless when the whole assemblage is taken together.

Much attention has lately been given to the fact that of individual variations some are transmissible by heredity and some are not; under the latter heading would generally fall somatic modifications directly induced upon the individual by conditions of environment. Whether any other kind of variation belongs to the same category need not for the present purpose come into discussion. But with regard to the undoubtedly transmissible variations, or mutations if we like to call them so, there is, I think, a fairly general consensus of opinion that they need not necessarily be large in amount. A complete gradation in fact appears to exist between a departure from type so slight as to be scarcely noticeable and one so striking as to rank as a sport or a monstrosity. And we know now that where the Mendelian relation exists between two forms, no amount of interbreeding will abolish either type; intermediates, if formed, are not permanent, and if one type is to prevail over the other it must be by means of selection, either natural or artificial.

In view of all these considerations I venture to think that there is no reason to dispute the influence of natural selection in the production of these remarkable resemblances. Other interpretations may no doubt be given, but they involve the ignoring of some one or more of the facts. It may fairly be claimed that the theories of Wallace, Bates and Müller, depending as they do on a basis of both observation and experiment, come nearer to accounting for the facts than any other explanation as yet offered. It will of course always be possible to deny that any explanation is attainable, or to assert that we ought to be satisfied with the facts as we find them without attempting to unravel their causes. But such an attitude of mind is not scientific, and if carried into other matters would tend to deprive the study of Nature of what to most of us is its principal charm. It is quite true that before the validity of any generalisation is accepted as finally and absolutely established, every opportunity should be taken of deductive verification. This has been fully recognised by the supporters of the theory of mimicry, and much has been done to test in this manner the various conclusions on which the theory rests. The verification is not complete, and perhaps never will be, but every successive step increases the probability of its truth; and probability, as Bishop Butler taught, is the guide of life. Meantime it is, one may say, the positive duty of everyone who has the opportunity, to fill up, so far as is in his power, the gaps that still exist in the chain of evidence. Here is an especially promising field for naturalists resident in tropical regions.

Before concluding this address, there are two points on which I should like to lay some special emphasis. One is the undesirability—I had almost said folly—of undervaluing any source of information, or any particular department of study, which does not come within the personal purview of the critic or commentator. 'I hold,' says Quiller-Couch, 'there is no surer sign of intellectual ill-breeding than to speak, even to feel, slightingly of any knowledge oneself does not happen to possess.' This is a temptation to which many of us are liable; and falls, I fear, are frequent. It was a matter of sincere regret to me to find one of my most valued scientific friends speaking publicly of the Odes of Horace as a subject comparatively devoid of interest. I can only confess my utter inability to sympathise with my friend's point of view. If he had merely said, 'excellent as those works may be, I have other things to do than to attend to them,' I could approve; but that is a different matter. The failing that I speak of is unfortunately by no means unknown among scientific men, and is perhaps rather specially prevalent when such subjects as those of my present address are in question. I can recall a very eminent man of science, no longer living, speaking with scarcely veiled scorn of those who occupied themselves with 'butterflies in cases.' This was in a Presidential Address to a Section of this Association. If so little respect is paid by a leader of science to work done in another part of the field, it is perhaps not to be wondered at

that one of His Majesty's Judges should speak of the formation of a great collection of butterflies—a most valuable asset for bionomic research—as the 'gratification of an infantile taste.' This or that collector may be an unscientific person, but it would be easy to show that the study of insects in general, and of butterflies in particular, is one of the most efficient of the instruments in our hands for arriving at a solution of fundamental problems in biology.

My second and final point is this. I have not hesitated to affirm my conviction of the importance in evolution of the Darwinian doctrine of natural selection. This necessarily carries with it a belief in the existence and general prevalence of adaptation. I am willing to admit that at times too much exuberance may have been shown in the pursuit of what Aubrey Moore called 'the new teleology.' 'Men of science,' it has been said, 'like young colts in a fresh pasture, are apt to be exhilarated on being turned into a new field of inquiry; to go off at a hand-gallop, in total disregard of hedges and ditches, to lose sight of the real limitation of their inquiries, and to forget the extreme imperfection of what is really known.' This is not the utterance of some cold outside critic, but of a great exponent of scientific method—no other than Huxley himself. It may be true of some of the wilder speculations of Huxley's date. I am by no means sure that there is not truth in it as applied to some of the developments of a later time. But however wide of the mark our suggested explanations and hypotheses may be, the net result of all our inquiries, after the gradual pruning away of excrescences and superfluities, will be a real advance into the realms of the unknown. We may feel perfectly assured that the objections so far brought against our own interpretations are null and void, but we may yet have to give way in the light of further knowledge. 'Let us not smile too soon at the pranks of Puck among the critics; it is more prudent to move apart and feel gently whether that sleek nose with fair large ears, may not have been slipped upon our own shoulders.'[1]

The following Papers were then read:—

1. *Some Further Experiments in the Artificial Production of a Double Hydrocœle in the Larvæ of* Echinus miliaris. *By* Professor E. W. MacBride, *F.R.S.*

In January 1918 I read a paper before the Royal Society in which I described a method of producing a second hydrocœle (*i.e.*, a rudiment of the water-vascular system) in the larvæ of the common shore-urchin, *Echinus miliaris*. During the last year I have repeated my experiments and obtained a complete confirmation of my previous results, with the addition of some further interesting details of which I propose to give now a short account.

The method which I outlined in my paper of 1918 was as follows:—The ripe urchins were obtained from Plymouth, and they were opened immediately on their arrival in London, and the eggs shaken out into clean sea-water which had been purified by being shaken up with charcoal and subsequently passed through a Berkfeld filter. After development had gone on for three days and the eggs had become transformed into four-armed plutei, these larvæ were transferred to water the salinity of which had been enhanced by the addition to it of 2 grams of NaCl per litre. In this hypertonic water they remained for seven days, and they were then retransferred to ordinary sea-water. At the age of about twenty-one days the extra hydrocœle which was situated on the right side of the larva began to develop. The experiment was only carried on till the larvæ were a month old, by which time metamorphosis had not been accomplished. The largest proportion of larvæ with two hydrocœles which was obtained in any culture was 5 per cent.

These experiments, which were carried out during the summer of 1917, were the culmination of a series which were begun in 1914 and carried on during the summers of 1915 and 1916. The reason that the larvæ, after being exposed to the hypertonic water for a week, were retransferred to normal sea-water was that I experienced great difficulty in getting the diatom *Nitzschia*, which

[1] Dowden.

served as food for the larvæ, to grow in the hypertonic sea-water. I naturally supposed that, had I been able to accomplish this, I should have obtained a much larger proportion of larvæ with a double hydrocœle. In 1919, accordingly, I instituted experiments with a view of attaining this end. I succeeded in obtaining a strain of *Nitzschia* which grew luxuriantly in hypertonic water; and three large cultures were instituted in bell-jars of 30-litres capacity, each fitted with a Browne plunger. In one of these there was normal sea-water, in which larvæ were placed which had never been exposed to hypertonic water; in another there was hypertonic sea-water containing larvæ which had been in this medium since they were three days old; and in the third there was normal sea-water in which were larvæ which had been exposed to hypertonic water for eleven days—*viz.*, from the time when they were three days old until they were fourteen days old. The result of these experiments was as follows :—In the jar containing larvæ which had never been in hypertonic sea-water no specimens with two hydrocœles were found; in the jar filled with hypertonic sea-water one specimen with two hydrocœles was found; whilst in the jar containing larvæ which had been in hypertonic water for eleven days 4 per cent. of the larvæ were provided with two hydrocœles. In all three jars the larvæ were exceedingly vigorous, and many of them completed their metamorphosis. Unfortunately, owing to the premature removal of the larvæ with two hydrocœles to a smaller vessel in which they did not flourish, none of them completed the metamorphosis, but this is not impossible, as I possess one larva obtained from a pre-war culture which actually accomplished this feat.

The conclusion to be deduced from these experiments is that retransferring the larvæ to normal sea-water after they have been exposed to hypertonic sea-water is an essential part of the process of producing a double hydrocœle. I hope next spring to be able to determine the length of exposure to the action of hypertonic sea-water which gives the optimum result. The question as to what is the reason of this necessity is not easy to answer. Of course, when Loeb used hypertonic sea-water to stimulate the development of unfertilised eggs, he found that there was a certain optimum time of exposure to this medium, but in this case too long exposure checked development and gave rise to only abnormal and sickly larvæ. But the larvæ of *Echinus miliaris* flourished exceedingly in hypertonic sea-water; and Loeb's explanation is therefore not available. I can only tentatively suggest the following :—The exposure to hypertonic water acts on a hidden rudiment in the larvæ and starts the right hydrocœle developing. But I have already shown, in my Royal Society paper, that the organs developing on one side of the larva tend to inhibit the development of similar organs on the other side. So, when the proper hydrocœle on the left side begins developing and gets a long start over its right antimere, it may check and eventually entirely suppress the development of this. The retransference to normal sea-water may possibly hold up temporarily the exuberance of development of the left side and allow the right side to hold its own.

If this supposition be well founded, Echinoderm development would afford a striking instance of that 'struggle between the parts' on which Roux has always insisted as an important feature of development.

In conclusion, I should like to say a word about the water used in these experiments. In performing the experiments, the results of which were given in my paper read to the Royal Society, I used sea-water collected at Lowestoft and sold by the Great Eastern Railway for bathing purposes. The distribution of this water ceased early in 1918. I tried artificial sea-water made with Tiedmann's sea-salt, but found that, although *Nitzschia* flourished in it, it was instantly fatal to both adult urchins and larvæ. I then had artificial sea-water made by the formula given by Dr. Allen (*Journ. of M.B.A.*, vol. 19), and found that it answered admirably, for the larvæ flourished in it and completed their metamorphosis in it. The fertilisation of the eggs, however, was effected in sea-water sent from Plymouth.

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2. (*a*) Leptospira icterohæmorrhagiæ *from the Kidney of local Rats.* (*b*) *Spirochæta* (*? n. sp.*) *from Guinea-pig.* *By* Dr. A. C. Coles.

WEDNESDAY, SEPTEMBER 10.

The following Papers and Reports were read :—

1. Iridomermyx humilis: *A Contribution to the Life History of the Argentine Ant. By* Dr. M. C. Grabham *(communicated by* Dr. F. G. Penrose).

The author described the insidious introduction of this ant into Madeira, its spread, and the complete suppression of competing species. It is established in destructive colonies up to 2,500 feet above sea-level. Coffee cultivation is ruined, and every sort of fruit tree—Citrus especially—which will support coccus or aphis is almost entirely destroyed. Sugar-cane and bananas still exist, though badly attacked; sweet potatoes (*Batatus*) have disappeared in many districts, a teeming population being thus deprived of a most important food. Every house is invaded and every kind of food carried off, and there is no winter weather to check the ant. Poultry, young birds, and bees are defenceless.

The author pointed out the methods and ingenuity of the ant in food-searching; how the ant transplants its pupæ into favourable conditions, and makes bridges to reach flies caught on sticky fly-paper.

The females are mostly impregnated within the formicary, and immediately afterwards shed their wings. Experiments show that the sense of smell is predominant. Reference was made to harmony in working and to the singular absence of fighting when separate communities meet. The ant's enemies are few; spiders devour them and *Pholcus phalangoides* is a formidable enemy.

One hope is in the eventual exhaustion and decreased fertility of the ant. Methods of control—singular effect of chalk powder; banding trees with rags soaked in corrosive sublimate is efficient.

By surrounding a lemon tree with a circle of powdered potassium cyanide every ant in passing to or from the tree was killed, and it was found that 40,500 ants had been tending the scale-insects on this one tree.

The progress of the ant in Madeira justifies American opinion that this pest is an agent of destruction as formidable as the Colorado beetle or the cotton-boll weevil. Our colonies should be warned as to the importance of this pest.

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2. *Sex Inheritance in Lice. By* Dr. E. Hindle.[1]

Pairs of body-lice were isolated and their offspring raised through five generations, but of sixty families obtained, twenty-four were mixed—*i.e.*, comprised both males and females—nineteen were female, thirteen male, and four crosses were sterile. The three sorts of families occurred simultaneously, although the lice were fed on the same individual and reared under the same conditions, and no explanation of their appearance could be discovered. The proportion of females to males in the total number of adults raised to maturity agreed almost exactly with that occurring in Nature (60 per cent. females, 40 per cent. males).

From the three types of families, four kinds of crosses are possible, and the results of a number of these are as follows :—

1. ♀ from a female family × ♂ from a male family; 11 families; 2 female, 5 male, 3 mixed (18 ♀♀ : 8♂♂), 1 sterile.

2. ♀ from a female family × ♂ from a mixed family; 7 families; 3 female, 2 mixed (15 ♀♀ : 2♂♂ (?)), 2 sterile.

3. ♀ from a mixed family × ♂ from a male family; 11 families; 3 female, 7 mixed (33 ♀♀ : 61♂♂), 1 sterile.

4. ♀ from a mixed family × ♂ from a mixed family; 3 families all mixed (10 ♀♀ : 19♂♂).

Different types of families were obtained by crossing the same female with two successive males, and also by crossing the same male with two females, these results suggesting the existence of two kinds of males and two kinds of females.

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[1] See *Journ. of Genetics*, vol. 8, No. 4, Sept. 25, 1919.

3. *Phagocytosis and Protozoa.* *By* E. S. Goodrich, F.R.S.[1]

4. *The Food of Larval and Post-larval Fishes.* *By* Dr. Marie V. Lebour.[2]

Further Observations on the Building Habits of the Polychæte Worm, Pectinaria Koreni, Mgr. *By* Arnold T. Watson, *F.L.S.*

The Abstract of a Note by the Author on the Habits and Building Organ of *Pectinaria* (*Lagis*) *Koreni, Mgr.* has appeared in the Report of the Proceedings of Section D. at the meeting of the Association in Birmingham, 1913.

Since then he has made further observations and experiments, as the result of which he has found that the suction therein mentioned, by means of which sand below the surface is removed by the worm for the purpose of forming working space, rapid burrowing and other purposes (the sand always travelling between the wall of the tube and the dorsal side of the worm) is not the result of ordinary peristaltic action, but is due to two currents through the tube (at opposite sides of the worm) which differ considerably in character, though both are the effect of waves produced by the worm's body.

The current produced by the dorsal body-wall of the animal, though it is sufficient to draw into the tube the sand swept to its mouth by the glistening head-bristles, is insufficient to expel it through the small end of the tube; and for this purpose it is reinforced by a much more powerful current, for production of which the ventral body-wall is specially adapted. This wall is exceedingly thin and mobile, while the dorsal is very thick, and consequently slower in action. The direction of the waves can be reversed and the worm is evidently mainly dependent upon the ventral one for supply of water for respiration. In production of the currents as described above the worm is assisted by the alternate extension and retraction of its body.

Owing to the head of the worm being always buried under the sand, and to the great number of tentacles which surround the mouth, it is impossible to see the building operations of the adult, but by observation of the post-larval stage (when the tentacles are few, and before the worm has dug itself into the sand) the author has been successful in seeing a portion of a sand-tube actually built and attached to the membranous tube, which at the time of its later metamorphosis is secreted by the larva. This membranous and characteristic tube is apparently secreted rapidly once for all by the whole surface of the body. It appears to consist of plates of areolated chitin. It is evidently indispensable to the future life of the worm, as apparently it cannot be replaced, and in its absence not only is it impossible to commence building the permanent tube for want of something to which to attach the sand, but the violent unrestrained action of the ventral body-wall when drawing water through the tube for purpose of respiration occasionally causes splitting up the middle of the back of the young worm.

In the early post-larval stage there are two buccal tentacles only; by these the minute particles ($\frac{1}{1000}$ to $\frac{1}{500}$ inch in size) are collected and passed to the mouth which opens at their base; here, what is required for food is swallowed, but such sand-grains as seem suitable for building purposes are rolled over for a short time in the mouth, and then deposited by it on the edge of the tube at the point selected; the young worm then advances slightly in its tube and, for four or five seconds, applies to that sand-grain the organ which, in the author's previous note, is called the 'building organ,' but which it is now evident merely supplies the cement from the cement-gland beneath.

In the adult worm there are numerous tentacles which collect the sand-grains, and in their midst a mobile membranous horse-shoe-shaped organ (not previously recorded by any naturalist), which no doubt (as in *Sabellaria*) guides the sand

[1] For an account of leucocytes of invertebrates described in this paper, see *Quart. Journ. Micr. Sci.*, Vol. 64, Pt. 1, p. 19; Oct. 1919.

[2] See *Journ. Marine Biological Assoc.*, Vol. 11, No. 4, May, 1918; Vol. 12, No. 1, July, 1919; remainder to be published in same journal.

to the mouth beneath. By the mouth the selected grains are placed in position, and then finally fixed by the cementing organ, described as a 'building organ' in the author's previous note. The nuchal organs of the worm were shown in position external to the tentacles on either side of the head.

Attention was called to a pair of long lateral glands, which are a striking feature in the post-larval stage. Possibly these may represent the large white glands of the adult, the function of which has been questioned. Lack of material prevented sections being made to test the point.

6. *Report of Committee on Zoological Station at Naples.*

7. *Report of Committee appointed to summon meetings for the consideration of matters affecting the interests of Zoology or Zoologists.*

8. *Report on Zoological Bibliography and Publication.*
See Reports, p. 122.

9. *Report on Inheritance in Silkworms.*

10. *Report of Committee on Marine Laboratory, Plymouth.*

11. Afternoon Lecture on *Lice and their Relation to Disease.*[1]
By Professor G. H. F. Nuttall, *F.R.S.*

THURSDAY, SEPTEMBER 11.

Joint Meeting with Section C, at which the following Papers were read:

1. *The Geographical Distribution of Freshwater Fishes, with special reference to the past History of Continents. By* C. Tate Regan, *F.R.S.*

2. *Palæontology and the Evolution Theory. By* D. M. S. Watson.

Afternoon Lecture on *Grain Pests and the Storage of Wheat.*[2]
By Professor A. Dendy, *F.R.S.*

FRIDAY, SEPTEMBER 12.

Joint Meeting with Section K.—See p. 339.

SATURDAY, SEPTEMBER 13.

Sectional Excursion to Lulworth Cove.

[1] For an account of the work referred to in this lecture see papers which have recently appeared and will shortly appear in *Parasitology*.

[2] For an account of the work referred to in this lecture see *Reports on Grain Pests* (*War*) *Committee* of the Royal Society of London.

Section E.—GEOGRAPHY.

President of the Section: Professor L. W. Lyde, M.A.

TUESDAY, SEPTEMBER 9.

The President delivered the following Address :—

The International Rivers of Europe.

This subject was chosen before the publication of the Treaty of Peace, and was dictated by a wish to combine my geographical creed with the political conditions of an 'Americanised' Europe. The Treaty embodies so many of the principles which I wished to emphasise, that my treatment should perhaps now be rather historical than political.

My geographical faith is in Outlook; the jargon of to-day is about Leagues of Nations. This is the day of nations and nationalities, and geographers must rejoice in the fact, because civilisation depends on a blend of varied influences—each an individual element, a *genius loci*—and the triumph of nationality must curb that tendency to a drab cosmopolitanism which would crush out all such variety. But these varied influences cannot blend into a progressive civilisation unless they have all possible facilities for friendly meeting; for instance, International Rivers should not be, like International Finance, anti-national, but really inter-national, 'between nations,' common to all nations, and encouraging the friendly meeting of diverse political elements and ideas. Liberty always makes for differentiation—in nations as in individuals; and if our international intercourse becomes really 'free' the desired variety is guaranteed.

This is why I would like to press the truth that Outlook is, or ought to be, the motto of geography. It is so for many of us, and it ought to be for all. But the word covers both a process and an objective. The Outlook is essentially over Big Mother Earth; the process is visualisation—the picturing of forms and forces, places and peoples, beyond the horizon, all possible horizons being included in the one great unit of the globe. But the geographical interaction of the Man and the Place cannot be dissociated—least of all in Political Geography—from the historical interdependence of group and group. Both alike are concerned with progress. We want to know, therefore, the whole simple truth—what the particular features and phenomena mean as world features and world phenomena, *not* what special meaning can be read into them, or extracted from them, by some local and interested political unit. Geography is, first of all, the visualisation of the world and the relations of the various parts of that world.

Now, the one predominant feature of the earth's surface is not land, but water. Nearly all international problems to-day have to do, explicitly or implicitly, with the ocean, *i.e.* with access to cheap water transport on the medium which covers three-quarters of the whole surface of the earth. Even the problem of Alsace-Lorraine, itself perhaps purely a land problem, conceals—especially from the Swiss point of view—a problem of access to the sea; and the problems of Poland, of Italy, of Jugoslavia, are obviously sea-problems or sea-problems very slightly disguised.

It is a truism that the ocean attracts rivers and their trade and their riverine population. Industry, commerce, even culture, have been starved and stunted in various parts of the world by lack of easy access to the sea. Even your League of Nations idea has more than once approximated to a substantial fact—round the Mediterannean and round the Baltic, facilitated by inter-national or inter-racial rivers. The Hanseatic League was essentially based on the relation of a number of more or less navigable rivers to an inland sea, and that was why it came to include such distant 'inland' members as Breslau and Cracow.

Accessibility is now more than ever before a supreme factor in all cultural and economic development, and rivers are still the chief natural intermediaries between land and sea. The first real international attempt to solve the problem of international rivers followed the victory of Sea Power over the France of Napoleon the Great; the second has followed the victory of Sea Power over this would-be 'Napoleon' of Prussia.

Now, I submit that to many of us the mere word *river* by itself suggests, at once and primarily, a physical unity—no doubt, with some variety of relief and climate—and that on this physical unity we are prepared to sanction some social and economic and even political unity. But directly you add the qualifying *international*, the suggestion changes; the adjective raises a picture not of local features, but of regional relations.

In recent years I have pleaded for the use of rivers as political boundaries—on the ground that they clearly separate lands without at all separating peoples except in time of war; we want to preserve the valuable variety of political and cultured units, but to draw the various units together. Our object is unity, not uniformity. The proposal has been objected to—even by some who are not at heart hostile to the idea of fostering all possible aids to the easy, honourable, friendly intercourse of peoples—on the ground that rivers shift their courses. They do, and trouble has come of this in the past, political trouble as well as economic. The Missouri was a fertile source of inter-State squabbles. But no normal person would *choose* a mud-carrier, like the Missouri, 'Muddy Water,' as a political boundary, unless there was a marked difference of racial type or nationality running approximately along the line of the river. In fact, I would suggest that the troubles along the Upper Missouri were really due to the fact that the river was *nowhere* an inter-State boundary, and therefore each State claimed the right to monopolise it in the particular section. If it had been an inter-State boundary from the first, such a claim would have been obviously absurd. And it was the iniquity of the claim to monopoly that forced the United States, as similar conditions forced the Australian Commonwealth, to take over the control of the inter-State rivers.

The principles behind the control are significant. Thus, the Murrumbidgee is entirely within New South Wales, as the Goulburn is entirely within Victoria; but the Murray is an inter-State river—in a double sense, acting as the boundary between New South Wales and Victoria, and emptying through South Australia. New South Wales has entire use of the Murrumbidgee, and Victoria of the Goulburn, but the whole volume of the Murray up to normal low-water level is left to South Australia. In Europe navigation is usually far more important than irrigation. Why should not Europe exercise similar control over the navigable rivers of Europe?

For, geographically, great navigable rivers are essentially a continental feature, *i.e.* really a world feature, for all major continental features must be included in a survey of world features, even if they are minor world features; and the world can recognise no right of a political unit to regional monopoly of the commercial advantages of such a feature to the disadvantage of other political units—least of all, others in the same region. As with the irrigation when a river is obviously and entirely within an area where identity of culture and sentiment proclaims a natural or national unit, there that unit has a claim—even if it should prove impolitic to press it—to some monopoly of the facilities afforded by that river. But when the river runs through or between two or more such natural or national units, *i.e.* is really international, one of the units has no claim to any monopoly against the other or others.

It was reasonable that expanding Prussia should get to the mouth of the Elbe, and it was certain that Holstein had been both a fief of the Holy Roman

Empire and in the German Confederation of 1815, and that succession in Holstein could *not* go in the female line. It was equally certain that Schleswig had never been in either the Holy Roman Empire or the German Confederation, and that succession in Schleswig *could* go in the female line. The reasonable sequel in 1864 would have been for Prussia to purchase Holstein from Denmark, and share the facilities of the international river.

One would not expect such a view to be taken by a Prussian, but that was the actual principle laid down by France nearly one hundred years earlier. The famous Decree of November 16, 1792, asserted that 'No nation can, without injustice, claim the right to occupy exclusively a river-channel, and to prevent the riparian States from enjoying the same advantages. Such an attitude is a relic of feudal slavery, or at any rate an odious monopoly imposed by force.' This was not mere talk. It was followed, in 1793, by the complete freeing of the Scheldt and the Meuse to all riparians—France herself being a riparian in each case, for the Scheldt was naturally navigable up to Valenciennes. Somewhat similar rights were extended, in 1795, to all riparians on the Rhine—France herself, of course, being again a riparian; and in 1797 the freedom was extended, so far as France was concerned, to the ships of foreign nations, though Holland was able to make the privilege valueless.

The original Decree had not pressed the precise question of internationality. But, if the general principle holds—that a great navigable river cannot be monopolised by a single political unit against riparians, even if they are its subjects and of alien 'race'—still more must it hold when the river in question is fully international, flowing through or between two or more States. Of course, Rhine, Danube, and Vistula do both.

As a matter of fact, in Europe this principle has been generally accepted for the last century except by Holland. Prussia and Saxony agreed about the Elbe in 1815, and the agreement was extended to Austria, Hanover, and Denmark in 1821. Prussia, Hanover, and Bremen made a similar agreement about the Weser in 1823; and Spain and Portugal made similar agreements about the Tagus and the Douro in 1829 and 1835. Holland, however, has a tarnished record.

One has not an atom of sympathy with the arrogant German demand that 'small nations must not be allowed to interfere with the development of great nations, least of all with that of the greatest of nations,' and that Holland—simply on the ground of her small size—should be robbed of her three estuaries in the interest of Germany. But neither has one an atom of sympathy with the Dutch habit of taking advantage of that small size to behave in a mean and unreasonable way on the assumption that no Power except Germany would use force against such a little people. I would like to illustrate the position by an analysis of the problem on a canal, for one must include straits and canals with rivers. Their inclusion may involve some difficulty, but in the most serious case the difficulty is already largely solved. I refer to the Panama Canal during the second year of the war, when British shipping was exactly half as large again as U.S.A. shipping, amounting to very nearly 42 per cent. of the whole traffic The total result of the war, however, has been a loss of over 5,200,000 tons of British shipping, involving a reduction of 13.5 per cent. in our carrying-power at sea, while the U.S.A. tonnage has increased by nearly 6,730,000 tons, *i.e.* an increase of 382.1 per cent. in the U.S.A. sea-going tonnage (June, 1919).

The case which I propose to analyse is that of the Terneuzen Canal, and I wish to press it with all possible emphasis because it shows a typical case of quite natural—and, therefore, almost pardonable—human selfishness, and because its supporters are guilty of an extraordinary blindness to their own mercantile *advantage*.

Ghent is the second port in Belgium, and the first industrial town in Flanders. In the days before the separation of the two countries it was connected with Terneuzen, *i.e.* 'open-sea' navigation on the Scheldt, by a canal twenty miles long, of which rather more than half was in 'Belgian' and rather less than half in 'Dutch' territory, the actual sea-connexion being—unfortunately—in the Dutch territory.

At the time of the Franco-Prussian War the Belgians decided to enlarge the canal, but had to *waste eight years* in obtaining the consent of the Dutch to the undertaking. Even then the consent was given only on the condition that the

Belgians should pay for all work done by the Dutch, give an annual grant of some £13,000 for the upkeep of the new works, and grant Terneuzen reduction of rates on Belgian railways! Some twenty-five years later it became necessary again to enlarge the canal; this was begun in 1895 on condition that Belgium again paid all the cost, that the Dutch had the right to close the locks 'whenever they deemed it useful to safeguard Dutch interests,' and that various other concessions were granted, *e.g.* about the Antwerp-Rozendaal railway; and the complete agreement was signed in 1902. The total cost was £1,600,000, a large proportion being spent *on the canal port at Terneuzen*; but the control is entirely in the hands of the Dutch, with the result that the Belgian part of the canal is both broader and deeper than the Dutch part, and the larger Belgian boats even now cannot reach Terneuzen! That is to say, after all the cost, the concessions, the delay, etc., the trade of Ghent is still hampered, and may be cut off at any moment. Of course, the stupidity of the Dutch in thus crippling their own trade is unpardonable; but what about Belgium? Even then her boats have only reached the Scheldt—a river of little use to Holland, but vital to Belgium.

I wish to press this case, because the two little countries have managed to live together in peace in spite of the serious 'international servitude' of Belgium to Holland, and because practically everything that Holland has done has been quite legal.

If Belgium has to pay almost the entire cost, she ought to have almost the entire control. The profit on the traffic is so great that Terneuzen has relatively heavier tonnage than any other Dutch port. A considerable part of the cost has been due to the canal having formed part of the Dutch border system, and under international control the total costs would have been met out of the profits.

Further, I press the point that, though refusals to grant facilities have been very rare, they have occurred, *e.g.* in 1906-7; and preposterous delays have been almost regular, *e.g.* a delay from November 11 till the following September 17 in granting permission to dredge a bank. Under international control all necessary precautions and facilities would have been supplied instantly—on their merits. Of course, I am far from wishing Dutch sovereignty to be displaced in favour of Belgian. I want international control in order to displace 'international servitude.' If what Holland has done has been legal, it is high time that it was made illegal.

It has been typical, too, that, when the Dutch have granted any facilities, it has been done by a specific treaty, *i.e.* done as a matter of policy, not of justice. It was from this point of view that they agreed to the Lek and the Waal being recognised as the proper mouths of the Rhine. This emphasis on policy rather than on justice has not, however, been confined to Holland, though she alone still adheres to it. In Europe, in America, in Africa, and even in Asia, there have been, first, attempts to enforce a so-called political right of sovereignty against neighbours, *e.g.* on the Mississippi by Spain, on the St. Lawrence by us, on the Amazon by Brazil, on the Zambesi by Portugal, and then special conventions somewhat on the lines of a Treaty of Commerce. Such treaties grant commercial facilities, and power of navigation is such a facility; but if the navigation is on a great continental feature, such as an international river, surely the particular facility should be admitted *without* any special treaty.

This claim has been specifically put forward on several occasions. For instance, by the Treaty of Paris (1763) we had the privilege granted to us of 'navigation on the Mississippi to the sea,' and '*to* the sea' meant '*out on to* the sea.' When the river passed under the control of the United States, the conditions were altered. Spain had granted no such facility to them, and she claimed the *political* right to block the estuary against them, while Jefferson claimed that they had a *natural* right to use the whole river, *i.e.* had such a 'right in equity, in reason, in humanity.' The same question arose on the St. Lawrence, where we claimed the political right to block the lower river against the United States in 1824. The case is specially important because Adams at once admitted the *political* right, *i.e.* the riparian 'sovereignty,' but claimed—as Jefferson had done—a *natural* right to use the river itself, a right which he

based on necessity and on the support of the political Powers of Europe as formulated in many conventions and agreements and commercial treaties.

There had been so many of these that it had become possible to generalise as to a common principle—really the principle of justice; and so the Treaty of Paris in 1814 and the Congress of Vienna had adopted the principle, and had passed general rules in sympathy with it, rules which have been applied to many rivers and even to canals—*e.g.* in the old Kingdom of Poland. In the particular case of the St. Lawrence, the water right would not cover any right of portage; but, of course, the international boundary comes to this river from New York State below the last of the rapids.

In 1851 Brazil claimed the political right to block the mouth of the Amazon, but this was universally condemned as a gross misuse of the right of riparian sovereignty, for the mouth of the Amazon is even more truly than the Dollart an arm of the sea—so truly that it separates two distinct faunas; and, as the Plate was declared free in 1852, Brazil could not in decency exercise her dubious 'right.' It was not formally given up, however, till 1867; and it lies implicitly behind the recent so-called 'concessions' to Bolivia.

Portuguese law raised a similar difficulty in 1883 on the Zambesi. Of course, Portugal was our oldest ally, and our relations were very friendly; but, though she neither controlled nor traded with the interior, she claimed the political right to block the estuary against us, and we admitted the *political* right so far as to consent to her imposing duties—which, in theory, might have been prohibitive of all trade.

The Zambesi is specially interesting because it was concerned with one of the first of those land-corridors about which there has been so much discussion lately—the 'Caprivi finger.' Everyone except our lawyer politicians knew the real object, the certain meaning, and the probable result, of our conceding that strip to Germany—though most of us pictured German troops marching eastward along it to cut the 'Cape-to-Cairo' route in Rhodesia, rather than Rhodesians riding westward into Ovamboland. But theoretically the Germans made a demand for access to navigable water on an international river, and we recognised this as a reasonable demand, and granted it. Here, again, we stand historically in a position of great moral strength. Further, if we accept international land-corridors and international air-corridors, we must accept also international water-corridors, such as a navigable river or a narrow strait.

I do not want, however, to press an African example, partly because I do want to repudiate entirely the application of the Berlin Conference to any rivers outside Africa. For in 1884 Africa was essentially a virgin continent, and its inhabitants were completely ignored—in theory by all the deliberators, and in practice also by the nation which had engineered the Conference. For one of Germany's essential objects was to converge on the Congo, and squeeze out Belgian interests; and eventually, to do that, she did not hesitate to employ the most unscrupulous propagandists in this country on 'Congo atrocities.' It was, therefore, part of her scheme to press—what was accepted by the Conference—that the Congo should be open to all flags for all commercial purposes, and that *no riparian rights* should be recognised. It was equally to her interest that the International Committee of Administration agreed upon should never be set up, and it never has been; and, of course, in 1911 she used the trouble which she had provoked in Morocco, to acquire 100,000 square miles of the French Congo, so that she became a territorial Power in the West as well as in the East.

The whole question has two aspects—(1) the freedom of the actual navigation, and (2) the administration of the river. The former is largely a matter of equity, and so did not appeal to the Dutch or Portuguese lawyers; the latter is largely a matter of law, and has been much complicated by legal subtleties. But the two are closely connected, for the European rivers with which we are specially concerned all have a lower course over the plain and an upper course involved in the folds and blocks of Central Europe. They are, therefore, important in the one case merely as carriers by water, and—all things considered, and in spite of superstitions to the contrary—are probably dearer as well as less flexible than the carriers by rail that cross them from west to east; thus the quantity of foodstuffs that reached Berlin—or New Orleans—by water in 1913 was quite insignificant. In the other case, however, they are of supreme

importance, for their valleys focus the whole commercial movement, *e.g.* of Switzerland, both by rail and by water. This puts the people of the upper river-basin commercially at the mercy of the holders of the lower; at least a third of the Swiss imports before the war were from Germany, and a fifth of the exports went to Germany—much, in each case, done under what the Swiss felt as 'compulsion.'

In this particular case the people of the Rhine delta were also—politically—at the mercy of the Germans. For the natural outlets of the Rhine basin, such as Rotterdam and Antwerp, had taken on naturally the international character of all great ports, while the river-towns behind them, such as Cologne and Frankfort, were nurseries of intense national feeling, most carefully and criminally fostered by the Government with the declared object of presently imposing that 'nationality' upon the 'internationalised' port. One way of entirely undermining a position offering such opportunities to the unscrupulous is international control, with its impartial improvement of the waterway *on its own merits*. Thus, in 1913 nothing like 1 per cent. of the navigation on the Rhine was British, while over 65 per cent. was Dutch; but the deepening of the Rhine up to Basel to admit sea-going vessels, *e.g.* from London or Newcastle, would instantly free the Swiss from their slavish dependence on *e.g.* Westphalian coal.

It is the political aspect, however, rather than the economic that I want to press for the moment. The economic aspect is useful only because it can be presented more easily in a statistical form, while the historic—though equally, if not more, illuminating—cannot be applied to recent events. We can see now that Peter the Great did not provide 'a gate by which (his) people could get out to the Baltic,' only one by which foreigners got into Russia; but we cannot have similar knowledge of the political value to Bohemia of the economically invaluable Elbe-Moldau. We can note, however, that it is essentially a way *out*, for the quantity of down-stream traffic (*e.g.* lignite, sugar, grain) is five times that of the up-stream traffic (*e.g.* iron, cotton, oils).

The agreements already mentioned, with regard to Elbe and Weser, Tagus and Douro, show that freedom of navigation has been granted as a reasonable courtesy for many years by nearly all civilised Powers, though even to this day Holland has persistently blocked progress by her stupid commercial policy and her unique position at the mouths of Rhine and Maas and Scheldt; and the essential principles are illustrated by the irrigation laws of Australia and the United States, where everyone now admits that the individual State cannot have any local standing, any riparian claims, as against the Commonwealth. All States, whatever their size or wealth or population, must be equal, though the natural advantages are with the upper riparians for irrigation as with the lower riparians for navigation.

The serious administrative difficulties are two—concerned respectively with the riparian sovereignty and with the different geographical conditions of different rivers or different parts of the same river; *e.g.* you can easily decrease the pace of the Rhine above Mannheim, but not without increasing the susceptibility to frost.

Historically, riparian sovereignty, in the case of Rhine and Danube, is only a relic of feudal robbery. When they first became part of the civilised world under Rome, there was no such thing as riparian sovereignty. They were public property, which had to be kept in order and improved; and for this purpose the Romans exacted dues, which were spent wholly and solely on the upkeep of the waterway. The Franks continued the same custom on the Rhine; but the feudal system brought in a horde of petty princelings—as impecunious as German princelings have normally been—who completely upset the old *régime*, converted public into private property, and exacted every kind of tax and toll. Unfortunately, because Rhine and Danube had been frontiers for Rome, they had been associated with a strictly military control, and the legacy of this favoured the feudal princelings—as it also helped to poison the whole political development along both rivers, for they got only the worst side of Roman civilisation. Now we must go back to the primitive conditions. If an international river is a world feature, then its world relation is the first consideration. In that case, riparians must tolerate representatives of the whole world, or of such parts of the world as are most concerned with the particular river, on the executive for the administration of the river. In most cases,

moreover, riparian sovereignty must be limited, even in the interests of the riparians themselves, for the presence of non-riparians on the executive may be, and has been on the Danube, of the greatest value in minimising friction amongst the riparians. In this respect France has played a most honourable part, generally supported by Britain, especially on the Danube, where, *e.g.*, Austria tried to exclude Bavaria from the deliberations about the river, and to dominate and intimidate the representatives of the lower riparians. Indeed, it was only the day before yesterday that we had the gratification of reading the German decision to 'exclude French and British representatives from the Danube Commission on the ground that they had hindered the ships of the more important nations from obtaining *priority* of treatment.' What greater compliment could have been paid to us?

The fact only emphasises the vital point referred to above, that different parts of the same river have different conditions and may need different treatment, *i.e.*, that even riparians have not all naturally equal use of the river, and that the strongest or the most favourably situated can grossly misuse their opportunities. The Dutch showed this on the Rhine in 1816, and the Austrians on the Danube in 1856. Obviously, such differences are, in themselves, potential causes of serious trouble; riparians have not necessarily and naturally real equality even when the executive consists of only one representative from each riparian State. The greater opportunities of expansion, political and economic, on the lower river may favour the growth of a stronger Power; and the State with the largest share of the river or the best position on it has already advantage over the others. For instance, the Dutch on the Maas and the Russians on the Danube have indulged in 'voluntary negligence'; it was in this way that Russia blocked the mouth of the Danube, and that Holland made it impossible for the Belgians to *continue* their commercial navigation on the Meuse down through Holland to the sea, though, since the discovery of coal in Limburg, the Belgians have—stupidly—turned the tables on Holland to some extent. A low riparian may no more monopolise or ruin navigation on the lower course of a river than a high riparian may poison or exhaust its upper waters. The river is a unit, and its unity is essential to the fulfilling of its duties in the evolution of world commerce; and, therefore, it needs a unity of administration. This is best secured by a commission of riparians and non-riparians, and such conditions facilitate the use of a river as a political boundary.

Nearly all the important details involved in the internationalising of navigable rivers have been illustrated already in the history of Rhine and Danube, and in both cases France has been an admirable guide to Europe. On the Rhine, as I have mentioned, she abolished in 1795 most of the restrictions which had made the river practically useless even to riparians; and that she was not thinking only of her own interests was proved by her attempt—defeated by Holland—to extend the freedom of the river to all nations in 1797. Again in the Convention of Paris (1804) France enforced unity of administration—sharing this with Germany on the ground that the river was of special concern to herself and Germany, as she has shared the administration of the Niger with us in recent years on the same ground.

The Rhine thus received a simple, just, uniform administration, which is a model for us now. All tolls were abolished except two—one on the boat and the other on the cargo—which were to be only large enough to meet the upkeep of the waterway, and were to be used for no other purposes. These tolls could be paid in each political area with the coin of that area, but a fixed ratio was maintained between the various coinages.

Of course, in 1815 France was ousted from the bank of the river; and in the reorganisation elaborated by the Congress of Vienna Von Humboldt, the Prussian representative, adroitly introduced into the regulations for the Central Commission of Riparian Representatives words which were afterwards made to mean exactly the opposite of the freedom enforced by France, and exactly the opposite of what our British diplomats at the time thought and said that they meant! Not only so; but during the sixteen long years while France remained more or less submerged, Holland was allowed to make the whole scheme ridiculous by the claim that 'to the sea' did not mean 'out into the sea,' and that a tidal estuary was 'sea.' The Regulations of Mainz gave each

riparian State full sovereignty over its own part of the river, and limited the right of pilotage to the subjects of riparian States; and in 1868 the Regulations of Mannheim further whittled down the old liberal principles of France—to the disadvantage of non-riparians, although they were admitted to rights of navigation. The Revised Rhine Navigation Treaty of that year was still in force in 1913, administered by the six riparian States—Holland, Prussia, Hesse, Baden, Bavaria, and Germany (as owning Alsace). Even since 1871 Prussia, as the strongest Power, has hampered the development of non-Prussian ports, using even the most childish tricks with pontoon bridges, choice of wharves, accessibility to rail, etc., against other German States.

Since 1871, too, the Rhine has illustrated another important point—namely, that the traffic on an inland waterway depends largely, perhaps vitally, on the extent to which railways are willing or forced to co-operate; and this has a present importance even from a purely international point of view. One of the results of the Franco-Prussian war was that Prussia bought up a number of private railways in the Rhine valley, and eventually used the profits of the transaction to make a secret fund for aggressive purposes. Now, if properly administered as an international waterway, the Rhine will be perfectly free except for trifling dues on boat or cargo for the expenses of upkeep; and it will compete so favourably with the Prussian railways that their rates will have to be reduced to a minimum. This will cut hard at such differential treatment as has handicapped British trade in the last twenty years, and it will leave no surplus with which the unscrupulous can juggle.

Of course, the Rhine is essentially linked with the Meuse and the Scheldt—politically, economically, historically; and the Powers have long been too lenient or too timid with Holland, possibly because her purely *legal* position appeals to lawyer politicians. The Dutch base their claims to monopolise the estuary of the Scheldt on the Treaty of Munster (1648), but have greatly strengthened their legal position in recent years. The marriage of the Dutch queen to a German princelet was followed immediately by the intrigue that ended in Belgium definitely granting to Holland special rights on the Scheldt in time of war, and Germany strongly supported Holland in getting these rights extended between 1905 and 1908. But the Scheldt is merely an international river; it is navigable into France, and it was only by France waiving her claims in 1839, and proposing a dual control by Belgium and Holland—like that of the Rhine by France and Germany at the beginning of last century, and that of the Niger by France and ourselves now—that Holland ever obtained the power which she has abused. When Napoleon annexed Antwerp, he declared the Scheldt free; and the Rhine Regulations, when extended to the Scheldt, were interpreted as meaning 'free for all flags out into the sea.' Even so, the Dutch raised every possible difficulty, and navigation had no fair chance until the railway from Cologne to Antwerp brought in the only kind of influence which the Dutch seem to understand.

We have, therefore, full knowledge of all the essential conditions necessary to ensure the proper administration of international rivers, and shall have no kind of excuse if we are caught napping or misled by plausible and 'interested' tricksters. Amongst their last tricks is 'the great difficulty of policing such a river, where a German boat may be stopped by a French official.' That is not more terrible than a Rumanian boat being stopped by an Austrian official; and the experience on the Danube shows that there is really no difficulty at all—for the simple reason that offenders are always dealt with, naturally and reasonably, by officials of their own nation, just as the various European Powers have the right of jurisdiction over their own subjects in the Belgian Congo. In Article 25 the effete and pharisaical Berlin Act of 1884-5 provided that its regulations for the Congo 'shall remain in force in time of war.' To-day we are less ambitious, and desire only to further safe, easy, honourable, intercourse, in time of peace, between nations that are unequal in size and population, wealth and power, situation and relation to navigation facilities. We have seen that one small nation may ill-treat another small nation from stupidity almost as easily and as grossly as a large nation may ill-treat a small nation from tyranny. Under the circumstances it seems necessary to remove from both the stupid and the tyrannical the opportunities for misusing such facilities; and the obvious way of doing this is to make international rivers international in use and in

government. Commerce is already a prime factor in the evolution of Human Brotherhood. Progress towards that ideal may be gauged as well by the price of a banana or a piece of chocolate as by the number of sermons preached on the subject; the sea is already free, made so mainly by British perseverance in clearing it of pirates; it only remains to make navigable rivers equally free, and the opposition comes mainly from those who have talked most loudly about 'the freedom of the seas.' But 'the freedom of the seas' does not mean that war is to be removed only from that element on which land power is weak, while the land power may still block access to the free sea by the natural avenue—the navigable river.

The following Papers were then read :—

1. *Three Years with the Staff and Two Months' Excavation in Mesopotamia. By* R. Campbell Thompson, *M.A., F.S.A., late Captain, Special Service Officer with Intelligence, G.H.Q. Staff, Mesopotamia.*

The object of the present paper is, first, to describe briefly the result of excavations, particularly at Abu Shahrain, and the examination of certain other ancient mounds in Lower Mesopotamia undertaken in the spring of 1918. After three years' service with H.Q. Staff during the war in Mesopotamia, Mr. (then Captain) R. Campbell Thompson was ordered by the War Office, at the instance of the Trustees of the British Museum (who proposed to carry on the Museum traditions of excavations in Babylonia as soon as the conditions of war would allow), to conduct these explorations. The present description of these diggings is a *résumé* of a paper read before the Society of Antiquaries last January (quoted in the *Times* of January 31), and the author's thanks are due to them for their courtesy in allowing him to repeat the main points of the discoveries described in his paper before their publication of the complete account.

The district in which these explorations were made is the area to the S.W., S., and S.E. of Nasiriyah, which lies about 100 miles W.N.W. of Basrah. This area, which may be described as Southern Babylonia, contains the ancient mounds of Ur of the Chaldees (Muqayyar), Eridu (Abu Shahrain), and several smaller mounds, including Tell-el-Lahm, Tell Tuwaiyil, Murajib, Abu Rasain, Tell Jabarah, Tell Judaidah, and another unnamed. Test trenches were dug in Ur (Muqayyar), but the greater part of the digging, lasting nearly a month, was carried on at Abu Shahrain.

Abu Shahrain lies twenty miles distant from Nasiriyah to the S.W., out in the desert, and at this time outside the 'protected area,' but fortunately the local Shaikh Hamud of the Dhafir was friendly, and on the ninth of April Captain Thompson started for the mound, with his Irish orderly, Pte. Thomas Higgins (one of the old 'Contemptibles'), fifty Arabs, and the Shaikh. All food, of course, had to be transported thither on camel-back from the nearest station ten miles away; there were wells within two miles of the mound containing enough water for the expedition, which camped just below the ancient mound.

This mound, Abu Shahrain (the ancient Eridu), has always been held to be one of the most interesting remains in Mesopotamia on account of the tradition of its high antiquity. It rises abruptly out of the flat, saline desert, the top of its slopes being about forty feet above the plain, and the perimeter about 1,100 yards. The ancient *zigurrat*, or temple-tower, crowns the N.W. portion, and rises another forty feet or more. The mound had been partly excavated by J. E. Taylor in the middle of last century, but the limitations of archæological science in those days prevented him from making the most of his discoveries.

The results of the present excavations are of the greatest importance for the pre-history of Mesopotamia. Hitherto the two peoples known to have occupied ancient Babylonia about the third millennium B.C. were the Semites (Akkadians) in the north, and the Sumerians in the south. But a quantity of fragments

of buff pottery, painted with black geometric designs, was found in these explorations at Abu Shahrain, and—although in far less quantity and sometimes only in coarse traces—even on the surface of five of the other mounds mentioned, which is exactly of the same kind as those found in the two lowest strata of Susa (the capital of Elam) and Mussian by the Dr. Morgan expedition. This Susian pottery, as is well known, bears a striking resemblance to pottery fragments found by the Pumpelly expedition to Anau about 300 miles E. of the Caspian. It is entirely distinct from either Sumerian or Semitic remains, and consequently we must now recognise the presence of a third people settled in very early times in this area in S. Babylonia, of the same stock as the peoples of Anau and Elam.

The stone implements of Abu Shahrain are numerous, and the expedition found quantities of flint, obsidian and crystal flakes, and about 400 chipped axe-heads similar in shape to those from Susa. Particularly noticeable even on the surface were the baked clay sickles, quite practicable for their work, and a large quantity of clay 'nails' always bent round at the point, similar to some found at Susa and Mussian. The large quantity of fresh-water mussels found in the strata, in contrast to the very few sea-shells, proves that the Persian Gulf was further from the mound than the great Euphrates lagoons.

From all indications it seems almost certain that these prehistoric Anau-Elamitic folk could not write. They must have been succeeded by the Sumerians, three kings of whom—Ur-Engur (*c.* 2400 B.C.), Bur-Sin (*c.* 2350 B.C.), and Nur-Adad (*c.* 2175 B.C.)—left inscribed bricks telling of their restoration of the *zigurrat*.

The more modern portion of the paper deals very briefly (with lantern slides) with the campaign, irrigation, towns, and mode of life of the inhabitants.

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2. *Surveys in Mesopotamia during the War.*
By Lieut.-Colonel G. A. Beazley, *D.S.O., R.E.*

Mesopotamia was unsurveyed before the Expeditionary Force landed in the country, the only maps available were the Indian Degree Sheets on the $\frac{1}{4}$-inch scale compiled from reports and travellers' sketches. Sir William Willcocks' skeleton irrigation maps were of great use, and were used to tie down both the ground- and air-photo surveys when triangulation was not available.

The Survey of India undertook the whole of the survey work and mapping carried out in Mesopotamia.

A survey party under Col. F. W. Pirrie, C.M.G., C.I.E. (who was also Deputy Director of Surveys), was organised, consisting of about seven officers, twenty-six surveyors, and 300 men, to deal with all the survey operations exclusive of air-photography and map compilation.

The survey personnel was organised briefly as follows :—

1. A detachment operating from Nasiriyah as its centre under Capt. W. E. Perry, M.C., R.E., who was responsible for all work in the Euphrates Valley, and whose detachment, after the fall of Baghdad, was strengthened, and carried the work up as far north as Hit and Falujah on the Euphrates, and up to the right bank of the Tigris.

2. A small section under Lieut.-Col. H. H. Turner, R.E., on the Tigris front as far as Kut.

3. The remainder of the party under Col. Pirrie filling in the blanks in rear of the fighting fronts, from the Persian hills to the east to the Arabian desert on the west.

Lieut.-Col. G. A. Beazley, D.S.O., R.E., succeeded Col. Turner (who was invalided) in October 1916, and was attached to G.H.Q. His detachment was responsible for all survey work on the Tigris front till some time after the fall of Baghdad. In May 1917 his small party was considerably strengthened, and its operations embraced all the country from Samarrah and Tekrit on the west to the borders of Persia on the east, and a portion of Persia itself.

4. Lieut.-Col. C. P. Gunter, O.B.E., R.E., was in charge of Map Compilation G.H.Q., and was responsible for all maps on various scales based principally on air-photography, and subsequently for all maps required by the force on various scales compiled from all sources of survey.

The small detachment under Col. Beazley was also responsible for (*a*) providing map compilation with fixed points to tie down the air-photographs; (*b*) providing batteries that required them with artillery boards; (*c*) fixing objects and targets in enemy territory and the sites of batteries.

The latitude and longitude of Fao at the mouth of the Shatt-el-Arab had been previously accurately determined by the Survey of India. The longitudes of Baghdad and Kermanshah were determined by wireless from Fao, the latitude of these places being known. On these co-ordinates the whole of the triangulation carried out was based.

No geodetic triangulation was attempted : the destructive proclivities of the Arab and the flat nature and unsettled state of the country put all scientific survey out of the question. All that could be attained was a general map of as large an area as possible on the $\frac{1}{2}$-inch scale, larger scales being used wherever required by the military authorities. Triangulation was for the most part confined to the more important rivers, the deserts and swamps elsewhere making more than a few extensions impossible; strong escorts were required, and transport on a liberal scale for water and rations had to be provided whenever the rivers were left.

The flat nature of the country made triangulation very difficult, involving a very large number of short-sided triangles; mounds were only occasionally met with. Mirage also greatly hampered the work; in the hot weather distant objects frequently disappeared at 10 A.M. and did not reappear till about 4.30 P.M. Under these circumstances it was impossible at times for the triangulation to keep pace with rapidly moving columns, and recourse had to be made to measuring distances by means of cyclometers fitted to bicycle wheels. As soon as the triangulation was pushed up behind the moving columns the scattered bits of survey based on (*a*) triangulation, (*b*) measuring wheels, were linked up and adjusted, more complete surveys of the areas covered being subsequently carried out.

An interesting experiment was tried by map compilation at Baghdad, which was quite successful, *i.e.* a 12-inch survey of the city based on air-photographs tied down to fixed points. The map was completed in about a fortnight. To have carried the same operation out by ground survey would have taken several weeks. When photographing from the air the neighbourhood of Samarrah in connection with a large-scale survey required by the military authorities, the outline in detail of a very large ancient city was revealed; the traces of walls, foundations, public gardens, etc., which were not visible to anyone on the ground showed up quite plainly on the photographs, and revealed the fact that surveys of areas for archæological research can in future be greatly assisted by air-photography.

A rapid means of topographical sketching from an aeroplane was evolved by Col. Beazley to take the place of air-photography over unmapped areas when time does not permit the latter process. By this method a map of the ground over which operations are contemplated can be very rapidly prepared and issued to the troops beforehand. Col. Beazley's aeroplane was shot down and he was captured by the Turks, stopping the work. Further experiments are now being carried out. The method is applicable to unsurveyed areas in arid countries when it is not desirable to incur the expense of air-photographic surveying.

3. *The Geographical Position and Site of Bournemouth.* *By* C. B. Fawcett.

Bournemouth is a new town and of a new type. As a town of any size it is barely forty years old. The O.S. map of 1811 showed the site as open heath land crossed by an unfenced road from Christchurch to Poole. There was one house, with a lodge, at Boscombe, and decoy ponds for wild fowl occupied the present site of the lower Public Gardens.

The town is built on a low wedge-shaped plateau between the Stour Valley and Bournemouth Bay. This is formed of unconsolidated materials, mainly tertiary sands and gravel. The Bay is in the axial valley of the Hampshire Basin, and the minor surface features are a result of this position and the physical history of that region. The depression of the basin let in the sea to produce the cliffs,

and lowered the base level of the small streams which have since cut out the chines. It also produced the sand beach.

The position of the town on the South Coast 100 miles from London is a prime factor in its development. It was beyond the reach of the cheap tripper, but within easy reach for the long-date visitor, and has become primarily a resort of the latter type of seaside visitor. It first appeared in the Census report in 1871, but not in 1881, and it became a borough in 1890 and a county borough in 1900, so that its growth has been very rapid. The striking feature in its population is the very high proportion of females to males : this has ranged from 1762 to 1556 to 1000.

Bournemouth arose after the construction of the earlier railways. The oldest line in the neighbourhood, the Southampton and Dorchester, was opened in 1847; it entirely ignores this town. Afterwards, as the town grew and gave rise to traffic, the lines were gradually extended to it. It is an interesting example of roads following the growth of the settlement—not preceding or causing the settlement.

For fresh water the town depends on deep wells. The site lacks surface supplies, and hence was unsuitable for dwellings before it was possible to distribute water from a distance—a fact which prevented earlier growth here.

It has no local industry, other than the retail occupations required to supply local needs. The most important sections of the population are :—

1. Persons who have retired from active life by reason of age or ill-health.
2. Persons here on long visits for reasons of health.

These account for the great excess of females, partly because the sons of such families are more generally out in the world than the daughters, and partly because they employ a large number of domestic servants. And while the direct government of the town is mainly in the hands of the local trading class it is dominated by the classes just mentioned. They are the spending section, and the town is organised for their comfort and convenience. Such towns are a direct result of those economic changes which have produced a new class in modern society, the class of wealthy, but non-localised people—shareholders who have no function in the industry from which they draw incomes and people living on pensions or savings. This class has made such towns as Bournemouth and determines its character.

WEDNESDAY, SEPTEMBER 9.

The following Papers were read :—

1. *The Future of Turkey. By* H. Charles Woods.

History has proved that the Near East has been the scene of, and the cause of, war after war, and from the moment of the entry of Turkey on the side of the Central Powers the problems connected with her future have been among the most important questions to come up for settlement by the Peace Conference.

For the purposes of that settlement Turkey means not only the areas which formed an actual part of the Ottoman Dominions at the time of the outbreak of the war but also the Ægean Islands, especially those occupied by Italy after the Turco-Italian campaign, the Island of Cyprus, and last, but not least, the districts of Erivan, Kars, and Batum, annexed by Russia after the war of 1877-1878.

Two principal conditions must be fulfilled in these areas. Firstly, safeguards must be established against a continued or a renewed danger of Pan-German control in territories the domination over which formed a prominent part of the ' Drang nach Osten.' And, secondly, the misgovernment and oppression carried on or permitted by the Turkish Government must cease.

These being the areas under discussion and the conditions to be realised, it will be found that there are certain already existing arrangements possessed of an influence upon the future. Among these arrangements, the effect of which was given in the paper, are the Treaty of Lausanne, the decision of the London Ambassadorial Conference in regard to the Ægean Islands, the then secret Treaty

made with Italy in 1915, the agreement made between Great Britain, France, and Russia in the spring of 1916, and, lastly, the terms of the armistice and the clause of the League of Nations Covenant which abrogates all obligations between members inconsistent with its terms.

The great question is whether Turkey is to disappear as a Great Power or whether her life is to be extended, more or less in its present form, though under efficient control. The adoption of the first alternative presents great difficulties, and it therefore seems necessary to seek a solution in the second. Coupled, however, with the maintenance of the Turkish flag, there must be adequate control at Constantinople and the fullest autonomy for the various nationalities of Asiatic Turkey. A united mandate for the whole Empire, especially were it an American or British mandate, would prove more workable than control carried out by a number of different mandatories.

The natures of the different States, or autonomous areas and their possible frontiers, present great difficulties, owing to the mixed population and to the rival claims which exist. Whatever, therefore, may be the subdivisions of the Ottoman Empire agreed to by the Peace Conference, as the populations of all the new States must remain mixed, steps should be taken to establish absolute equality before the law for minorities and majorities, for Christians and for Moslems.

In conclusion, two vastly important questions must come up for settlement in connection with the future of Turkey. The first concerns the regularisation, and, if possible, the unification, of the several systems of jurisprudence existing in the Ottoman Empire—systems necessarily to be inherited by any newly-created States, unless measures be taken to put an end to or to modify them. And the second is bound up with the financial position of the country—her pre-war public debt and other liabilities—a position which must receive the most careful consideration if precautions are to be taken to prevent these burdens from being unfairly distributed in the future.

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2. *Some Geographical Aspects of Nationality and Internationalism.* *By* Marion I. Newbigin, *D.Sc.*

In one of its aspects the war was a conflict between the older ideals associated with the National State and the newer conception of Internationalism, based upon the development of modern industry. Broadly speaking, it may be said that the former so far has conquered in the western section of the Continent, with its great diversity of surface, and the latter in the wide uniform plains of the east. For while Belgium has been restored and France re-established in her old boundaries, the aims of the party still dominant in Russia are definitely anti-national. Thus while the internationalists aimed at substituting for the old-established National States of the west a greater unit with a purely economic basis, their success has been limited to a region where neither nationality nor modern industry has attained full development. Similarly, whereas the internationalists claim that just as the National State rose from local groups or separate city States, as the result of an improvement in communications, so the greater unit of the future is the inevitable consequence of modern means of transport; in point of fact, their doctrines so far have only prospered in an area where these are poorly developed. The paper examines the factors which have determined the rise of National States and endeavours to show that these are a response to largely unalterable physical conditions, and are therefore destined, in one form or another, to persist as against the conception of the industrialised International State.

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3. *Ethnic versus Economic Frontiers of Poland.* *By* Miss M. A. Czaplicka.[1]

The war has made familiar such expressions as 'Geographical,' 'Historical,' 'Ethnic,' and 'Economic' frontiers. The 'Geographical' frontiers are the only ones upon the definition of which everyone agrees, *i.e.*, frontiers marked by

[1] To be published in *Scottish Geographical Magazine*.

water, mountains or any other boundary making geographical feature. Favourable geographical frontiers are merely important for strategic purposes.

The definition of 'Historical' frontiers is the most debatable since several countries may claim to have held a certain frontier at various times. A consideration must be made here as to whether a frontier is gained by a country through conquest, an economic colonisation against the wish of the inhabitants, or else by arrangement with the local inhabitants. Finally, the stability of a historical frontier and the conditions accompanying it are not to be disregarded.

'Historical' frontiers are of special importance in the case where there is a question not of altering the frontier, but of establishing it anew, if the country in question did not possess political independence at the time preceding the making of the frontier. This is the case with Poland. Before trying to define what frontiers she ought to have, if they are to be based on racial grounds, and what if the minimum economic necessities are considered which would provide her with material independence, it is necessary to recall to memory Poland's last frontier. Such was her frontier of 1772 before the period of the partitions, which frontier with small variations she enjoyed for some four or more centuries. The historical frontier of 1772 included some 760,000 sq. km., and the territories thus united in Polish hands, if non-Polish ethnically, were acquired by dynastic and other arrangements. At various times Poland extended over a larger area, *e.g.*, when she included the lower Dnieper, the original home of the Cossacks, but those were acquisitions based on conquest and she did not possess them in 1772.

The last hundred and fifty years have made great changes in the political orientation of some of the inhabitants of the Polish lands of 1772. The Poles did not become Germanised or Russified, but in that part of the Polish State coming under the Russian *régime*, which was composed of several other nationalities besides the Poles, Russificatory measures stimulated a national revival, and brought even a quite new national awakening to the Ukrainians, Lithuanians, Letts and Esths. Thus the fact that on the territory of the Poland of 1772 there live to-day some 53 millions of people, of whom 38 per cent. are Poles, makes much greater difference now than it would have in 1772. In short the ethnic principle demands that some 369,000 sq. km. of old Poland be ceded to the newly constituted national States. The remaining 391,000 sq. km. forms what people call ethnic Poland, *i.e.*, where the Poles form an absolute majority. The historical claims are stronger in that case, for naturally these lands form the cradle of the Polish race. If the Peace Conference had wanted to make definite Section 8 of the Treaty and had followed the ethnic principle this would have been the limit of Poland to-day, and she would have formed a more truly national State than any other in Eastern Europe.

The economic principle often does not coincide with the national one, a difficulty which has arisen in all newly-formed countries. In the case of Poland it does roughly coincide, and to the two districts the only ones which are sometimes considered ethnically debatable—Gdansk (Danzig) and Eastern Galicia—the economic and historical claims of Poland are particularly strong.

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4. *The Dodecanese.* *By* O. H. T. Rishbeth.

The name to most signifies little more than 'a few barren rocks,' yet the historical associations, economic standing, and apparent political value of these islands call for consideration. The name ('Twelve Islands') has been variously interpreted as to its content, but in questions of frontiers it is clear that all those islands lying off the south-west coast of Asia Minor, and which are not yet Greek, are meant. They stretch from close below Sámos on the north to Rhodes on the south-east, towards the Cyclades westwards, and towards Crete southwestwards, and from the south-eastern part of the 'Grecian Archipelago.' They appear to be mainly a fragmentary fringe of the south-west Asia Minor coast, though others (Kárpathos, Káros, Astypalaia) seem links of westward-stretching former mountain chains, of which they are the unsubmerged summits. They are mainly small barren crags with deeply bitten and often precipitous coasts, hilly or mountainous, devoid for the most part of streams, natural vegetation, and girt by dangerous seas. Rhodes and Kós are larger and are exceptional in many of the above respects, and they have fair stretches of level

ground. Geologically the islands are related to south-west Asia Minor and Crete, and volcanic formations and agencies prevail in the more northerly isles. The climate is on the whole temperate, but the rainfall for the most part is scanty, and the islands are exposed to winds often violent and treacherous. Conditions of human existence, with some exceptions—notably Rhodes and Kós—are hard: there is little arable ground, often little water, and ceaseless toil is necessary to maintain cultivation. Methods are backward, and Rhodes, mainly owing to Turkish occupation, is largely undeveloped. Most of the islands produce some fruit, vegetables, grapes, olives, a little corn, and live-stock. Some are able to export a little; others are not self-sufficing even in these respects, and all depend largely on the import of grain and other commodities. There are no industries of importance; the mineral resources have not been tested, and, with the exception of sponge-fishing—which is interesting in itself, the sole means of livelihood to some of the islands, and productive of considerable wealth—marine pursuits are unimportant. The people—nearly all Greeks—are simple, hard-working, enterprising, and hardy, patient agriculturalists, cunning mariners, daring and skilful fishermen. They are becoming more sophisticated with the growth of better communications and Western ideas. Their historical social institutions are highly interesting and show them to possess a strong sense and capacity for self-government, not inferior to—though little better than—that of ancient democratic States. They are devoted to education and religion (Greek Orthodox Church). The nature of their towns and sites of settlement is also instructive. The chief motives controlling the choice of these are evident and are climatic and economic, but far more those of security, especially security from pirates. The development or shifting of the site from seashore to lofty crag and *vice versa* reflects accurately the phases of historical evolution in the Ægean as well as modern commercial influences. Rhodes has an historical interest of its own. The modern towns are mostly solidly built, prosperous, and well kept, occupying striking sites on harbours often naturally fine. The standards of education, comfort, and personal refinement are fairly high, especially in the richer sponge-fishing communities. Rhodes is more backward. The population was about 120,000, all of whom, except some 16,000, were Greeks, but during the last ten years emigration has gone on apace. The islands have had a chequered history, but under Turkish rule (1522-1912) enjoyed a large degree of autonomy and throve upon it. The Turks became oppressive in proportion as the islands grew wealthy. The Italians occupied the islands in 1912, and subsequently retained them as a guarantee for the Turkish evacuation of Tripoli, and the outbreak of the European War found them in the hands of Italy, to whom they were later pledged in the 'Secret Treaty' of 1915. The Greek claim to the islands is based on racial and linguistic, historical, religious, and sentimental grounds. But the possession of these islands, while not without economic profit (*e.g.* Rhodes, Kós, in agriculture and minerals; Syme, Kálymnos, etc., for sponge-fishing) is valuable mainly for the facilities they offer—with their fine natural harbours—for the exploitation of the south-west Asia Minor (Adalian) coast, and for the control they afford of the Ægean communications with Syria and Egypt.

5. *The Geography of Imperial Defence.*
By Vaughan Cornish, *D.Sc., F.R.G.S.*

International security is founded on the fact that no Government commands nearly half the population and resources of the world, so that none can engage the rest with a prospect of success. Consequently, the one purpose common to the foreign policy of each Government is the prevention of dangerous preponderance by any other. At present there are about fifty Sovereign States, of which seven administer about two-thirds of the world and its population. Of the remaining third the Chinese constitute one-half, so that the minor States, about forty in number, have only one-quarter the population of the seven Great Powers. Consequently, strategic geography to-day is concerned chiefly with the territorial relations of the Great Powers, and with certain strategic positions between their territories which are in the occupation of lesser States. The British nation is unique in its geographical condition, for

it alone occupies racial homes on each ocean. Consequently, before the national army can be concentrated, parts of it must be conveyed great distances by sea, which can only be achieved in security if a supreme navy be maintained. All other nations can concentrate their armies by railway, and therefore to none of them is a supreme navy essential, as it is to the British. A second peculiarity of the British Empire is the inclusion of the vast Indian population. For each British subject there are in the world only three foreigners, a fact which by itself goes far to provide a humanitarian justification of that supreme navy on which the continuance of the Empire depends.

The geographical position of the Empire may appropriately be described by reference to the ocean instead of the continents, since the communications are maritime. The United Kingdom and the chief entrance to Canada are on the Atlantic Ocean; South Africa, India, and Australia are ranged round the Indian Ocean, with New Zealand in the adjacent part of the Pacific. Thus the maintenance of naval communication extending halfway round the world suffices, without the necessity for crossing the other half of the circuit, which is comprised in the Pacific Ocean. The naval communications are, therefore, relatively short, and they are improved by an unrivalled selection of intermediate harbours at natural junctions of maritime routes. The coastal communications of Great Britain and the Colonial communications of the Empire are flanked by the territories of the French Republic much more closely and extensively than by those of any other Great Power. In addition to possessing good naval communications, the territories of a maritime State should be difficult of approach from the continental interiors. This condition is fulfilled in the British Isles and Australasia by their insularity, in India by a great mountain barrier, in Egypt by deserts, and in South Africa by remoteness and the barrier of tropical forest. In Canada alone, which has restricted maritime access and a very open frontier, is there a marked discordance between geographical conditions and strategic requirements. The neighbourhood of the British Empire and the American Republic is, however, not confined to the common frontier, but is also to an important extent upon the sea. This results from the dependence of the American Republic upon maritime communications for the maintenance of the Monroe policy, upon the outpost of Panama, which is required for the maintenance of coastal communication, and upon the sea for almost all foreign commerce except that with Canada itself.

Australasia and India being nearer to Japan than to Great Britain the strategic position is locally advantageous to the Japanese, but this is offset by the great maritime superiority of the geographical position occupied by the British Empire as a whole and the United Kingdom in particular. It should also be noted that the security of maritime communication in general is an important common interest of both States.

Egypt not only provides the shortest naval connection between Great Britain and India but the only route for the railway connection between our African and Asiatic possessions. It is also at the junction of the air routes from Great Britain to South Africa on the one hand and to India and Australasia on the other. Owing to the disruption of the Turkish Empire no one Government now has power to provide protected communication from the Bosporus to the Egyptian frontier, or to Mesopotamia, which is one of the approaches to India both *via* Persia and the Persian Gulf.

Formerly the foreign policy of Russia and Germany so conflicted in reference to Constantinople that an *entente* was impossible. Now that this position is beyond the attainment of either, the advantages of alliance should be obvious to both those nations. If possessing a common frontier, so that their complementary resources could be pooled without possibility of interference, they would have all in the way of men and material requisite for a prolonged war on the largest scale. At one end of their combined territory railways reach the borderland of India, the most vulnerable portion of the British Empire. The other end faces the most vital part of the Empire, Great Britain—the chief recruiting base of white troops, the chief factory and shipyard. Germany has excellent harbours within three hundred miles of Great Britain, and adjoins the Low Countries, which provide in the harbours of the Rhine and Scheldt the best base from which to invade the citadel of our Empire. In

order to prevent the pooling of resources by Russia and Germany it is important that the reconstituted States of Eastern Europe should form a complete intercept. Hence the importance of securing the continuity of Rumania and Poland by the restoration of Eastern Galicia to the latter State. The reconstituted States of Eastern Europe will form a continuous territory with population and resources equal to those of a Great Power. We shall have naval access to Jugo-Slavia by Adriatic ports, and to Rumania by the newly-opened Black Sea. Holstein and Southern Schleswig being retained by Germany, that State will have opportunities for military control of the Kiel Canal in the event of war, thus jeopardising our naval communications with Poland.

Such are the outstanding facts in the defensive geography of the British Empire as now constituted; but if, as has been proposed, the Government of Great Britain and Ireland be separate instead of united as at present, a vital change in the conditions would result. The real vulnerability of Great Britain is not to invasion but starvation by blockade. The area *per capita* is less than half that of France, which country has only just enough land to feed its people. No system of farming at present generally practised will make Great Britain independent of foreign food. This comes across the North Atlantic and Bay of Biscay, since Western Europe has little to spare. Even if there were through railway communication by a Channel tunnel, supplies by this route would be dependent on the grace of foreign Powers. Thus if Ireland be governed separately from Great Britain the subsistence of the population of the latter would be dependent on the controllers of the Western Island, which flanks the routes from the ocean, and is at present the naval outpost of the United Kingdom. The passages past the Irish coasts are also the routes by which reinforcements and munitions must be sent to the dominions and territories beyond the ocean from Great Britain, the main recruiting and munition base of the Empire. Thus if Ireland and Great Britain were politically separated neither Great Britain nor the outlying dominions and territories would be strategically secure.

THURSDAY, SEPTEMBER 11.

1. *Discussion on Geographical Aspects of Evolution*, opened by the following Paper:—

Some Geographical Aspects of Devolution in England.

By C. B. Fawcett.[1]

The prominence of 'Devolution' during this time of reconstruction may be ascribed to three principal causes, namely:—

1. The strength and urgency of the Irish demand for some form of home rule, and the existence and growing strength of similar demands in Scotland and Wales.

2. The congestion of business in Parliament and the fact that the present Parliament is obviously unable to cope with all the tasks which fall to it.

3. The increasing realisation that our counties and county boroughs are too small, in area and in the authority of their councils, to deal adequately with many problems of local government.

The realisation of these facts has led to many references, in the Press and from public platforms, to a 'federal solution.' This is usually understood as involving the erection of four national Parliaments—in England, Scotland, Ireland, and Wales—to deal with the internal affairs of each country.

The fatal weakness of this solution, as it is thus stated, is that one of the four partners possesses more than three times as much population and wealth as the other three together. The German Empire was the one prominent example of a federal State in which one partner was dominant—and Prussia was less

[1] See C. B. Fawcett, *Provinces of England* (London: Williams & Norgate, 1919).

dominant in that Empire than England would be in a federal Britain. In most federal States no one member is dominant; this is the case in Canada and Australia as well as in the United States and Switzerland. Experience suggests that it is better that no single member of a federal State should be able to outvote all the rest. These considerations lead to the suggestion that in a federal Britain England should enter as a number of provinces rather than as one unit. This would require a division of the country into suitable provinces, a division which must be based primarily on its geography. Each province should be comparable in population with Wales and Scotland.

There are in England a number of distinctive regions of this order of magnitude of which we may mention East Anglia, the Devon Peninsula, Yorkshire, and the North Country. The last two of these are more populous than Wales, and the others have each more than a million inhabitants.

A division of England into such provinces should be based largely on a study of the present distribution of the population. The existing distribution into counties is, for the most part, based on divisions which grew up long before the Industrial Revolution, and the resulting great increase and shift of the population which has taken place in the last 150 years. Hence the new provinces cannot be based directly on the counties. The principles on which such a division could be made may be set out as follow :—

1. Provincial boundaries should be so drawn as to minimise interference with the everyday movements and activities of the people.

2. Each province should have a definite capital, which should be the real focus of its regional life.

3. The least province should contain a population sufficiently numerous to justify self-government.

4. No one province should be able to dominate the federation.

5. Provincial boundaries should be drawn near watersheds rather than across valleys, and very rarely along streams.

6. The grouping of areas must pay regard to local patriotism and tradition.

(Of these Nos. 5 and 6 may be regarded as corollaries of Nos. 1 and 2.)

There should be no effort to secure uniformity, of area or of population, among the provinces. Any such attempts would inevitably produce very unsatisfactory and unstable groupings of population, and boundaries which would handicap rather than facilitate effective organisation of public services in the provinces.

Several of our larger provincial cities have already become well-developed regional capitals, centres of the economic and social life and thought of populous regions. Among these we may place Newcastle-on-Tyne, Leeds, Sheffield, Nottingham, Manchester, Birmingham, and Bristol. Each of these is also an important node in our road and railway systems, a university town, and the seat of an important press. Hence each could well serve as a capital for one of the provinces.

The following Papers were then read :—

2. *The Site of Westminster.* *By* H. Rodwell Jones.

The original importance of the site of Westminster seems to have lain in the fact that it formed a sandy eminence rising slightly above the saltings of the Thames flood-plain at a bend in the river where the stream was probably fordable and where there was an easy passage for boats. There can be little doubt that the Roman surface, which now lies some nine feet below high water, lay originally at much the same height relatively to the level of the Thames as the actual surface does to-day. Whether this change of conditions be due to a gradual sinking of the Lower Thames Basin or to a gradual increase in the rise of tide as a result of embanking it is difficult to decide. Probably both influences have been at work.

Thorney Island, on which the Abbey was built, is often spoken of as part of a delta formed by the Tyburn. Geographically speaking, this is an unfortunate description. It is not the habit of the Thames tributaries to form deltas. In almost every case the tributary stream enters the main river on the outer curve of a meander. Westminster flats lie opposite to the outfall of the Effra, those of Fulham to the confluence of the Wandle; the formation of

the meander being due probably to the inflowing tributary in the first instance. The natural confluence of the Tyburn would seem to have been at the Westminster bend, in the neighbourhood of Whitehall. Once the stream had left the gravel-capped plateau, whose brink lies along Piccadilly and debouched into the floodplain to the north of Buckingham Palace, its course may easily have been diverted again and again by accident or intention. It may at one time have joined the Westbourne, or its waters may have been turned into one or other of the numerous tidal creeks that drained the flats at low water.

It does not seem possible to determine whether Thorney was a natural or an artificial island, though the collection and plotting of excavation records in sufficient number may eventually help us to some conclusion.

The course of the Tyburn in its upper and middle reaches, on the other hand, may be easily traced, and can best be seen on the contoured map sketched from the bench marks and ground levels given on the Ordnance Survey maps of 5 feet to the mile. A street map, however, that gives minor lanes and alleys will show the line the stream traced clearly enough to the observant eye, and its valley is still fairly obvious to anyone who has the patience to track it out.

From the geographical point of view the main interest in the site of Westminster focuses round the work of tidal river and tributary stream in controlling movement and settlement.

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3. *Some of the Conditions Governing the Selection of an Aerial Route.* *By* Colonel Towler, *R.E.*

The purpose of this short paper is to describe some of the peculiarities of aircraft and their effect on the conditions aimed at in selecting an aerial route.

An abstract of the requirements is as follows. The various items being considered individually, that route giving the best average fulfilment would be the one selected.

1. The first requirement is safety.

Oversea flights in a land machine should, if possible, be not longer than half the distance a machine can glide, without her engine, from the height at which it is customary to fly.

A suitable number of possible landing places available so that in the event of engine failure a machine will, at any time, be within gliding distance of at least one. Good and frequent meteorological information obtainable when required so that risk of accident through sudden formation of fog and mist may be small.

2. The second requirement is speed.

The distance from the starting point to the destination should be the shortest possible in order to economise in time and fuel.

In the event of a forced landing the telegraph and railway should be near so as to be available to forward news immediately of the position and requirements of the aeroplane. Another machine can then be sent to complete the journey with the passengers or merchandise, or again the necessary spare parts for the repair of the machine which has landed can be sent by air or rail.

The requirements as to communication may in many instances be fulfilled by the wireless telegraph or telephone installation carried in the machine.

3. The third requirement is that the route shall have a number of distinctive landmarks to help the pilot in his navigation by recognition of position.

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4. *The Static Power of Melting Ice.* *By* A. Trevor Battye, *M.A.*

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5. *Crete.* *By* A. Trevor Battye, *M.A.*

FRIDAY, SEPTEMBER 12.

The following Papers were read :—

1. *Colonisation in Africa.* *By* Sir Alfred Sharp, *K.C.M.G.*

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2. *Persia.* *By* Lieut.-Colonel G. S. F. Napier.

Why the independence and prosperity of Persia are important to England on strategic, commercial, and political grounds :—First British Mission to Persia. Early Persian diplomatic relations with European Powers. Napoleon's intrigue in Persia. Russian and Turkish encroachments on Persia in nineteenth century. Russian intrigues. Germany's policy to prevent any understanding between Russia and England. King Edward the Peacemaker. Anglo-French Entente. Anglo-Russian Convention of 1907. Spheres of interest in Persia. The new Anglo-Persian agreement. Order and security in the provinces and cheap and efficient transport the crying needs of Persia. Robber bands. Extinction of the powerful robber combine under Reza Khan Juzdani and Jafar Kuli in the Isfahan area and of the Jangalis under Kuchik Khan on the shores of the Caspian. Shortage of transport animals in Persia owing to the war and to famine. Active resumption of export and import trade delayed by present heavy cost of transport. Provision in new agreement to co-operate in railway construction and other forms of transport. Importance of motor transport to develop the country and act as pioneers to the railways. Advantage of unlimited cheap petrol from the Anglo-Persian and Baku oilfields. Existing roads available for motor transport. Railways to the frontier on east and west and new Bushire-Borasjun line. Tehran, Roads therefrom. The Lynch road from Tehran through Kum and Kashan on to Isfahan. The Isfahan-Shiraz road. The road from Baghdad.

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3. *Some New Experiments in Atmospheric Electricity, and their Possible Connection with Terrestrial Magnetism.* *By* E. A. Reeves.

The experiments described in this paper resulted from investigations made in the subject of Terrestrial Magnetism, and appear to show that there is a more or less permanent static electric field in the lower atmosphere, with its lines of force connected with the rotation axis of the earth. The question of the possibility of a connection between this supposed field and the magnetism of the earth is raised. With a special apparatus it is shown that a strip of paper or other light material, when electrically charged and covered with a glass shade, coated with shellac varnish, will, if placed on a stand and set up on high open ground away from obstructions, come to rest within a degree or two of the true north and south points. In exceptional circumstances the line indicated is approximately at right angles to this line, that is, true east and west; but still the connection is with the rotation axis of the earth, and not with the magnetic meridian. Observations have been made in various parts for years past, and the results of some of these will be shown at the meeting. The apparatus and method of using it are described, and the state of the atmosphere, localities, and other conditions under which the observations are likely to give the most satisfactory results are given in detail. When the indicator does not come to rest it continues to oscillate on either side of the true north and south points, and the mean of these is very nearly the line of the rotation or geographical axis.

The principal object the author has in bringing the results of these observations to notice, now for the first time, is that they may induce others to take an interest in the subject and continue experiments in other parts of the world. So far his own experiments have only been carried out in South-East England, but one or two friends have obtained much the same results in other parts of the country, and abroad.

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4. *Air Photography.* *By* Colonel Winterbotham, *R.E.*

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5. *Aeroplane Photo Surveys in the East.* *By* Captain H. Hamshaw Thomas.

Section F.—ECONOMIC SCIENCE AND STATISTICS.

President of the Section: Sir Hugh Bell, *Bart.*, *C.B.*

TUESDAY, SEPTEMBER 9.

The President delivered the following Address :

At last, after an interval of three years, the British Association resumes its meeting and takes up the business which the Council decided to suspend during the period of the war.

The meeting at Newcastle in 1916 found the world plunged in warfare of a most destructive character, and left us unable to determine either the extent of the destruction or the probable period of its continuance. Few would have then believed it possible that the following year would find the situation unchanged and the outlook at least as black as in 1916. Much less would it have been believed that in the summer of 1918 we should be in even greater anxiety as to the final outcome, and that not till the early winter of that year should we be relieved of the nightmare of horrors under which we suffered in the five years which have elapsed since August 1914.

It is said that at a very early stage Lord Kitchener foretold a war of five years, and on his interlocutor protesting and expressing his belief that such a thing was impossible, reduced his estimate by one year, 'provided Russia held out so long.' The collapse of Tsardom coming when it did may be taken as fully justifying Lord Kitchener's estimate, for not till three months of the fifth year had run out were we greeted with the joyful news of the Armistice. Many months had to elapse before the Armistice was ended by a treaty of peace with our chief opponent. Even then we found ourselves engaged in more or less active warlike operations in various parts of Europe, Asia, and Africa. To-day we are still unable to review in any but a preliminary fashion the economic or other results of the war as a whole. We shall have to wait till long after our meeting at Bournemouth before a complete survey is possible.

Meanwhile, let us, in passing, take note of the fact that the cessation of hostilities did not carry with it the cessation of expenditure. The figures given each week in the *Economist* show the daily disbursements of the kingdom to have amounted to $6\frac{1}{2}$ million pounds for the twenty-one weeks from November 16 to April 12. I append a table giving them for the twelve weeks prior to the date of the Armistice and for the twelve weeks following it, omitting the week in which it fell. It will be seen that whereas from August 24 to November 9 our expenditure amounted to $585\frac{1}{2}$ million pounds, from November 23 to February 8 we expended 564 million pounds, a reduction of only $21\frac{1}{2}$ million, or about a quarter of a million a day. This means that the debt with which the war burdened us continued to augment long after the cause of it had ceased to operate. The Chancellor of the Exchequer's statement in August that the expenditure even then exceeded four million pounds a day against pre-war expenditure of £541,000 shows that we are still vastly exceeding our income. Even if we take into account the interest on the war debt, which amounts to about one million pounds a day, it is clear that the various obligations undertaken by the Government during the war continue to impose on us a huge expenditure which is largely in excess of our revenue.

We have been led to believe that the expenditure of the last five years had gone, in part at least, into channels which would leave us with profitable and realisable investments. Some time will be required to demonstrate this, and we may still hope that the sale of the national factories will bring some relief to the burden of debt. It may be admitted that the process of 'cleaning up' is necessarily costly and slow, but it would be satisfactory to be able to record that the 'assets,' whether fixed or floating, had been of sufficient value to pay for their realisation, whereas we are being fed on the unsubstantial hope that at some future date vast sums will flow into the Exchequer as the 'surplus stores' remaining on hand in November 1918 are turned into cash, and the various factories sold or put to some useful purpose.

A cause of yet greater apprehension is to be found in the fact that new claims are made on the national purse and are accepted with the same apparent light-heartedness and disregard of consequences which mark so many previous acts of those responsible for our expenditure both during the war and before it.

We must recognise that we could not ask the multitudes of women who came forward to meet the call for munitions of war of various kinds, and for even more direct and active service at home and abroad, to abandon their activities and return to the conditions which satisfied them prior to the war. A like observation applies to the men who accepted the call of the nation and gave up their accustomed work to serve their country at the Front or at some employment at home quite different from that to which they had been used. Some compensation for these sudden changes was no doubt inevitable. The disorganisation of the whole industrial machine made it difficult, if not impossible, to turn these different classes adrift into a world in the chaotic condition into which the war had thrown it. But it does not follow that this compensation should have been given in a way actually to encourage unemployment. Tales, more or less authentic, pass from mouth to mouth indicative of the results of the ill-considered plans adopted to meet the difficulties which were no doubt most serious. The Irish farm labourer, offered a job at 30*s*., who replied, 'Sure, I'm not likely to work for your honour for 1*s*. a week; I'm getting 29*s*. for doing nothing,' is one of these. The girl typist, paid the quite inadequate wage of 15*s*., who gave up her work and at once received unemployment pay at 25*s*., is another. Let us hope that the story of the navvy found smoking under a hedge, and, reproached for his idleness, who rejoined that 'he was engaged in working overtime at Cippenham,' is a fable, but it is of sort in which an unkind world may detect an element of truth. Whether true or not, these observations are of little importance in themselves except as indications of a general tendency to extravagant expenditure which must be checked before the course of our economic existence can return to normal lines. It should be the purpose of all patriotic citizens to accomplish that return at the first possible moment. To enable us to do this we must consider what has happened to the world economically since August 1914.

The first and perhaps most striking change to be noticed is that in these five years an immense quantity of wealth has been destroyed. I have had the sad advantage of paying a visit to the countries where the destruction can be seen. From the Belgian coast to Verdun, over a stretch of country from ten to as much as twenty miles or more in breadth and not less than 400 miles in length, I passed through a land where the effects of modern warfare were painfully visible. It is impossible to convey to those who have not seen it the extent and completeness of the destruction. For miles every sign of cultivation has disappeared. The trees with which in places the country was covered are represented by dead, unsightly stumps. We were told that these were useless even as firewood. They are so full of morsels of steel that it is impossible to cut them down or saw them up. They must stand till they rot. We passed through the pitiable remains of what the ruined walls and defaced gardens showed to have once been a village. But even more frequently we saw heaps of broken stones and bricks which, but for a board with a name on it at the side of the road, might have been taken for merely a more stoney and dishevelled piece of country. The epithet just used is more appropriate than one who has not been an eye-witness could suppose. The immense quantities of barbed wire which are being gradually

gathered up look like the fantastically ugly coarse tresses of some gigantic maenad.

Even more pitiable were the towns which bore still some semblance of life, just as a wounded creature inspires more compassion than one from which life has departed. Arras, for example, of whose beauty some traces remain in the picturesque great square and the adjoining Petite Place, with its lovely Town Hall, evokes a more poignant sorrow than Albert, or even Ypres, where the gaunt ruins of the Cloth Hall and Cathedral bear hideous testimony to the destruction worked by modern war. In all that part of the country the poor quality of the building materials have made the ruins most unsightly. As the traveller goes further east he comes into a region where a fine building-stone produces better houses and less unsightly ruins. But even there a shell makes a very hideous wound, and the remains, such as they are, have none of the dignity which Time bestows on human structures which have fallen into decay under his more kindly hand.

It forms no part of my subject to deal with the æsthetic side of the question, but I cannot refrain from expressing the horror with which I saw the ruins of Reims Cathedral. What has been said of the effect of shell-fire is infinitely true of the appearance of this wonderful monument of human art and human piety. Would it were possible to let it stand just as it is, taking means to guard it from the weather and from further damage, but not attempting to restore it to its pristine glory. The beautiful remains would be a perpetual monument to the shame of those who brought this irreparable injury to one of the most splendid examples of architectural art.

There must be many hundred thousand acres of cultivated land, with the apparatus required for its cultivation, which has been reduced to the condition I have endeavoured to picture. It is difficult to see how it can ever be brought again into use at any early date. The mere clearing away of the wire entanglements to which I have referred must be a costly operation. Great quantities of shell abandoned by the Germans in their hasty retreat still cumbered the ground they had occupied. These must be carefully removed—not a very simple operation, and one which must be carried out under skilled direction.

We saw numbers of ungainly tanks, the result of British ingenuity, left where their valiant occupants had been compelled to quit them. At one place we counted six of these in the space of a few acres. The removal of one of them was being effected by a valid tank, which was hauling a derelict to some place to be repaired or, more likely, to be broken up. I dwell on all this to try to bring home to you what must be done before what was once a smiling, prosperous countryside can be brought back to the state in which we saw the land lying outside the battle area on either hand.

Can anyone doubt the huge destruction of wealth which has occurred? But it is really worse than it appears, for the very process of destruction was even more costly than the damage done. Millions of tons of steel in the form of guns and their projectiles—millions of lives had gone to produce this untoward result. For fifty months all the energies of the most active and energetic people on the globe had been turned from beneficial enterprise to such work as that which produced the result I have sought to portray to you.

When all these things are considered it is not surprising to find our estimate of the cost of the war reaches a total the mind cannot grasp. When you begin to speak of pounds by thousands of millions the difference between twenty-five and forty is hardly noticeable. But be the sum larger or smaller, the all-important fact to be borne in mind is that the wealth which it represents has passed out of being.

So much confusion exists on this subject that it is worth while dwelling on it for a moment. Some contend that there has been a mere change of wealth from one ownership to another. Into whose possession, may we ask, has passed the wealth which used to exist in the towns and villages and cultivated land of the battle area? It is true that the steel which went to effect this destruction has been paid for, but from what source has that payment come? Let us think what might have happened but for the war. The steel might have made rails and been laid on a railway to bring the produce of

Central Africa to lands ready to pay for it and desiring to consume it for useful purposes. For all time there would have arisen in the process an income which would have gone to support in comfort those receiving it, and its surplus, after this had been effected, would have served to add yet more miles of railway and to bring yet more tons of useful produce. All this energy has been dissipated in the manner indicated, and all that remains is the obligation of the 'State' for all time to pay interest on a debt which has been created.

There is, as it seems to me, but one way to escape from the situation we have created. No measure of confiscation, however disguised, will remove the burden under which we lie. It may be decided to alter the incidence of the burden from one set of shoulders to another. Any proposal of the kind must have very careful and earnest consideration. If two men are journeying together, one carrying a heavy pack and the other none, it may well be that by dividing it they will reach the end of their journey sooner than by one carrying it all. But do not let us imagine that there is less to carry because it is borne by two instead of one.

It is sometimes said that all taxation is in the nature of confiscation. Is this really a valid contention? In the ordinary way, taxes are levied for services rendered or to be rendered. It is indeed true that the tax is frequently not in proportion to these services. There is good reason to hold the opinion that at one time, if not now, the wage-earner paid by means of indirect imposts, which then were his only contribution to the revenue, an amount out of proportion to his income. It cannot be doubted that, what with tax and super tax and, in a certain measure, excess profits tax, the possessor of a large income pays much in excess of his percentage share towards the revenue. In each of these cases the excess payments smack of confiscation.

If a really sound and equitable scheme of taxation could be devised each taxable unit would contribute to the common fund raised for the purpose of the Government an amount which would be arrived at after due allowance was made for his services to the community and his ability to pay. A bachelor, with no claim on him but to support himself without State aid, who had done nothing to provide for a citizen to take his place in the fulness of time, might be called upon to pay more than a man under obligation to maintain a family and supply by his children the means of carrying on the torch of progress.

All kinds of refinements suggest themselves which show how difficult it is to give effect to the dictum that the amount of the tax should be regulated by the 'ability to pay.' It might, for example, be suggested that, since the thrifty man is better able to pay than the thriftless, some exemption should be granted to the latter. A graduated income tax presents the hope of a solution of the problem. Professor Edgeworth in the *Economic Journal* of June 1919 deals very elaborately with this question. He mentions the scheme proposed by Professor Castle in 1901, and says: "Distinction may be claimed for it on the following among other grounds: It is elementary, 'intelligible to the most untaught capacity,' a great merit in a principle of currency, according to Mill, and doubtless some merit in a principle of graduation." It may perhaps be questioned whether the pages which follow this quotation are so easily 'intelligible to the most untaught capacity' as Mill and the learned professor suppose. We may also doubt whether a careful man would fully appreciate the introduction into the equation of a modulus representing that particular ground for exemption which would cause him to pay relatively more tax than his less thrifty fellow.

One of the chief objections of graduation seems to be the danger of gradually increasing the steepness of the scale till the higher incomes would be taxed out of existence and the revenue they produced disappear. This would no doubt bring its own remedy. The State needs a certain annual revenue to provide the services demanded by the community. If the result of taking much the greater part of incomes over a certain amount ends by extinguishing these the State will cease to derive the revenue on which it counts. It must then either reduce the tax on them till a point is reached at which they will continue to exist, or it must increase the tax on all or some of the other incomes. Unless it means to rush headlong into bankruptcy, it must find the point of equilibrium at which its scheme of graduated taxation continues to produce the revenue

required, not in any one year, but in all future years. Such a scheme, could it be discovered, would meet entirely that very important desideratum of a tax, namely, that it should be based on ability to pay.

Two other points must be kept in view. A tax must be equitable in its incidence and reasonably continuous in its imposition. Given these three conditions the economic burden of the impost will quickly fall on the right shoulders. We may dismiss the argument which asks for a levy on capital and defends it against the accusation of being confiscatory on the ground that it is no more confiscatory than any other means of raising money by the State. No juggling with the balance sheets of the nations of the world will get rid of the fact that many thousands of millions of wealth slowly accumulated in the generations which lived before August 1914 have been dissipated.

If we confine ourselves to the more manageable figures which relate to our own activity we find that our public debt has risen from 710½ million pounds, at which it stood in 1914, to the colossal sum at which it stands to-day. The history of the debt in the hundred years preceding 1914 had been one of almost continuous reduction. From just over 900 million pounds in 1816 it fell to 628 million pounds in 1899. There were periods when the fall was arrested. In 1905 it had risen to 798 million pounds—a figure comparable to that of thirty-five years earlier. The Boer War was chiefly, but not entirely, responsible for this increase. In 1914 it stood considerably above the lowest point which it ever touched, but in the preceding eleven years every year but one showed a marked reduction.

In the last five years all this has been changed. From August, 1914, to March, 1915, 450 million pounds were added. The next year added more than 1,000 million pounds. By March, 1917, it stood at 3,906 million pounds, and now it has nearly doubled and is more than ten times what it was at the outbreak of the war.

It is true we have something to set against this vast sum. We have acted as the financial agents of our allies. The sums we have found for them amount to close on 2,000 million pounds. On the other hand, we have ourselves contracted debts abroad to the extent of well on to 1,500 million pounds. On balance, therefore, we have interest to receive on about 400 to 500 million pounds. But to enable the inhabitants of this country to find money for our Government we have sold fully as large an amount of our holdings in foreign securities. On balance it may be contended that we are little worse off. I fear in closer examination this view will not be found good.

Let us admit that our allies will find no difficulty in paying the 100 million pounds a year or thereabouts due for the interest on their debt to us. We must recognise that this will make a serious draft on their resources. Very different were the securities held by individuals in this country with which they parted to take up each successive issue of Government Bonds at the urgent insistence of successive Chancellors of the Exchequer. The securities sold were usually first-class industrial or public-utility issues. They might be the obligations of a Government in the wisdom and stability of which confidence could be placed; or the bonds of some great and progressive city, the money having been used to bring water to the inhabitants; or shares in some commercial undertaking to further the development of the country. In the great majority of cases we may assume that they had been invested so as to produce, directly or indirectly, a revenue to meet the interest. What have we got now? A charge on a heavily burdened country of which, it may be, many thousand acres have passed into the condition I attempted to describe a little while ago. I fear if an accountant from the planet to which Mr. Gladstone told us years ago we had banished political economy were to pay us a visit he would regard with no favourable eye the balance sheet which placed at their full value debts of the sort we are considering.

Put at the highest not many of our millions of pounds will find their own interest. All the balance must come out of the product of the other and real industries of the debtor country, and to this branch of the subject we must now turn.

At the present moment it is of more vital importance than ever that we should come to a clear and unprejudiced understanding on this subject. To

judge by appearances, the vaguest and most unsatisfactory opinions exist as to the capacity of the community to meet the various claims which are preferred for a share of the wealth from which alone these claims can be satisfied. Many people seem to think that no demand is too exorbitant. We are asked to provide houses by the hundred thousand undeterred by the consideration that they will cost two, three, or even four fold the amount at which they could have been built before the war. They are, moreover, to afford accommodation of a much better character than was thought sufficient a very short time ago. Houses built as recently as twenty years ago are no longer good enough for the social reformers of to-day. It is forgotten that something like 80,000 houses are needed each year to accommodate the growth of the population. There are to-day something over eight million inhabited houses in Great Britain. Not more than half of these are more than fifty years old. During the war housebuilding had almost ceased, but before 1914 the building of houses had been checked by two causes. The various Acts of Parliament dealing with matters affecting the building of houses had so enhanced their cost that there was the greatest uncertainty whether houses could be built to return a reasonable interest on their cost.

But the second cause was of as great, or possibly even greater, significance. The trade unions connected with the building trades had gradually succeeded in imposing conditions which had added enormously to the cost of building. It would not be difficult to show why this had been possible, but it would take me too far to follow this line of thought. The fact will not be denied by anyone conversant with the circumstances. The result of all this is a serious shortage of houses, and this it is proposed to make up by grants from the public purse. If this were the only demand of the kind we might face it with more equanimity than is in fact the case. But when we look elsewhere we see other claims comparable in their effects on the public purse but differing in kind.

The railway enterprise in this country may serve as typical of what is meant. Prior to the war the railways were carrying on their duties in a manner which enabled the country to get through its business in a profitable and, on the whole, fairly satisfactory way. They earned sufficient revenue to pay a fair return to the shareholders. It is true the prospect was not reassuring. The railway management was meeting the usual contradictory claims preferred against almost every industry. It was asserted that they were rendering services which were not nearly as great as were demanded by their customers, and they were charging for them rates which were regarded as quite out of proportion to the value of the services. On the other hand, they were paying wages which the recipients thought entirely inadequate for much longer hours of service than their workmen were disposed to give. Negotiations between the parties had obtained certain concessions as to hours of work, and also as to rates of pay; but these were not accepted as sufficient, and Parliament was called upon to intervene, with the result that statutory hours were imposed.

The very essential difference between hours of work or rates of pay resulting from convention between the parties interested and the same imposed by statute is often overlooked. The convention can be varied to meet the varying circumstances. The statute provides a hard and fast rule, from which it is impossible to depart without incurring penalties. An example of this may be found in the Cleveland Ironstone Mines, which, by a series of strange accidents, come under the Coal Mine Regulation Acts, and are thus subject to all the conditions imposed by statute on coal mining. Employers and workmen are agreed in desiring to modify the provisions of the Acts as to hours of work on Saturdays. Their joint application to the proper Department for permission to do this has been refused for reasons which that Department (quite properly) regards as unanswerable. The officials decline to exercise a dispensing power and require that the provisions of the Act be rigidly followed.

When the railway companies pointed out the serious effect which these statutory obligations imposed on them had on their revenue-earning capacity and sought power to increase the rates their customers were up in arms. The very men who, in Parliament and elsewhere, were applauding the decision to give relief to the railway servants resolutely refused to pay the extra cost thus incurred. With difficulty was Parliament induced to give the

companies leave to add to their charges something towards meeting this cost. The companies found still greater difficulty in obtaining a settlement with their customers as to the amount which should be so added. The question was still awaiting a final settlement at the outbreak of war.

But the case of the railways seems irrefragable. They point out that their earnings are barely sufficient to meet the claims on them and leave a suitable return to their shareholders. And when answer is made that these critics and customers are indifferent as to this, they point out that, unless they can do it, they will be unable to meet the demands of the districts which they serve. No railway serving a prosperous and growing district can continue to render the services required unless it is able to raise capital to be expended on the provision of those additional facilities for which the expansion of the district calls. But to attract capital the railway must be able to show a revenue of which the surplus, after meeting all expenses, will serve to pay adequate interest. Even before the war, the never-ceasing demands of the workmen, and the ever-increasing obligations placed on the companies by Parliament as to the facilities to be given, were rendering it more and more difficult to find the necessary capital. It cannot be said that the return to the shareholders of all classes was inordinate. The 1,300 million pounds of railway stock earned a surplus of 50 million pounds in 1913—not quite 4 per cent. It is evident, therefore, that one or other of the following things must happen. Either the railway development must cease, and with it, to a large extent, the development of the country, or the revenue must be increased per unit of traffic, or the expenses must be diminished either by reduction of the actual charges or by improvements in the methods of operating.

We may dismiss the first of these possibilities, for we must decline to believe that the country will cease to develop. It would be with great reluctance that we should accept an increase of the charge per unit of traffic. We would rather hope that by adopting better operating methods we should reduce costs and so reduce charges. It is to this side of the question that we must address ourselves. In doing so we may pass from the special case of railways to the general case of the national industries.

There has been a persistent demand by labour throughout the country for better pay, and an equally persistent demand for more leisure. To these demands no objection can be taken. On the contrary, rightly understood, they must meet with approval by all who desire to see the country, as a whole, happy and prosperous. But we must consider how they can be satisfied. This is a question to which recently a great deal of attention has been given. In its satisfactory solution lies all our hope for the future.

To begin with, the only source from which satisfaction can be is the sum-total of the product of the industry of the country, and indeed of the world, in the period under consideration. It must be noted that in many cases the product may not be realised within that period, as, for example, when a manufacturer holds large stocks of goods which he has not yet marketed, but on which much the greater part of the cost has been paid. It must also be noted that a very considerable part of the industry of the country does not add to the total product which is the subject of division, but is in fact a charge on that product. The whole burden is borne by those engaged in providing commodities or services necessary for the members. We touch at this point a very difficult problem, the proper solution of which may possibly show us how all our economic troubles may be ended. I can do no more than state it as briefly as may be.

There can be no question that a very great part of human activities is spent, and the resulting product used, in providing things which cannot be called necessaries of existence. The simplest food, clothing, and shelter may be said to cover all that comes under this head. But life that gives us nothing but the indispensable minimum of these essentials would be so dull and monotonous as to be hardly worth the exertion needed to procure them. We must have more than these if we are to get enjoyment as well as mere life. How much more can we claim—perhaps we might say, extort—from our environment? And how shall this extra tribute be shared among us?

If we made a complete analysis of the result of the product of industry we should be astonished to find how large is the amount which remains after the

essential demands have been satisfied. Take a survey of some town you know and ask yourself what the multitude of public-houses and picture-palaces indicate but a spending of money on non-essentials. Or look nearer home, and consider whether the things you could quite easily spare do not bulk very large. If we sought to classify our expenditure we might come to some such division as this :

On essential needs.
On things making for the irreproachable amenities of life.
On luxuries which add to and aid our reasonable enjoyment.
On those which subserve mere pleasures.
On extravagant expenditure for which no justification can be offered.

It is difficult to draw any clear line between the heads of this very rough division. Each class passes imperceptibly into the next. Fortunately for our present purpose we do not require to do this. It is enough that we should admit that not all activities are well directed, and that we consume a great many things we could do without. No class is exempt from this blame, if blame it be. Each is disposed to look askance at what is called the extravagance of some other. When people talk of waste, they often mean expenditure on things for which they themselves do not care. But the question is how can we check this extravagance and provide more fully for the more essential needs of the whole people?

If rich men did not drive motor cars or drink costly wines, would the people who produce these luxuries be better off? Or if, instead of making these things, they made articles needed for the mass of the people, could these buy the result if they had no more means than they now possess? Do we not come back at the end to the proposition that men can only have more if they have more to offer in exchange? The great mass of mankind labours to gain 'daily bread.' If more is produced, more of these necessities will be satisfied.

It may be contended that men have obtained more or less completely what they wanted most urgently. They wanted shorter hours. In many trades they have got them, and might have had them in more had they gone about it in the right way. They were not sufficiently desirous of having better houses, and they failed to procure what their wellwishers desired for them. It remains to be seen whether the movement in this direction, to which reference has already been made, will produce the results which we all desire to see—though some of us would like to see them obtained under more satisfactory economic conditions than are at present proposed.

A relatively small part of the population do unquestionably get a very large share of the total income produced by the whole community. Can we do anything by which this share may be reduced without bringing about greater evils than those we seek to overcome? The history of the sumptuary laws do not encourage much hope that attempts to prevent expenditure in particular directions will have much success. My own studies had brought me, many years ago, to the conclusion that in every industry examined there is no way of giving to those engaged shares greatly differing from what has been afforded in the past. The margins on which manufacture in general is conducted are too small to make it possible to give the larger contributors to the ultimate result any considerable addition to what they have been accustomed to receive. This impression was confirmed by the elaborate general survey of the industry of the kingdom carried out by the Census of Production of 1907.

No doubt labour (which is much the most important item of cost) has obtained a gradually increasing payment, though not necessarily any larger proportionate share. A steady improvement in the methods in which the labour of men is applied has resulted in enabling a larger product to be obtained. Each new implement, each fresh application of energy of various kinds, as, for example, steam and electricity, has meant that the individual man produced more in his day's work, and he got, in fact, a larger return for what he did. But at the same time, the capital engaged was increased, and consequently the proportion of the product to be allotted to rewarding capital also increased. It is neither possible nor desirable to attempt to alter this state of things.

The whole question has been treated in a very masterly way by Professor Bowley in a book published some months ago entitled 'The Division of the

Product of Industry,' a title I had myself adopted for a lecture I gave at the National Economy Exhibition in July 1916. Mr. Herbert G. Williams's pamphlet entitled 'The Nation's Income' also deals with the same subject with much care and skill. In it he makes a critical examination of Sir Leo Chiozza Money's book entitled 'Riches and Poverty.'

The conclusion reached in these publications is practically the same. It may be stated in the cautious words with which Mr. Bowley ends his book :—

"This analysis has failed in part of its purpose if it has not shown that the problem of securing the wages, which people rather optimistically believe to be immediately and permanently possible, is to a great extent independent of the question of national and individual ownership unless it is seriously believed that production would increase greatly if the State were sole employer. The wealth of the country, however divided, was insufficient before the war for a general high standard; there is nothing as yet to show that it will be greater in the future. Hence the most important task—more important immediately than the improvement of the division of the product—incumbent on employers and workmen alike, is to increase the national product, and that without sacrificing leisure and the amenities of life."

These statesmanlike words need to be borne in mind by all who are engaged in dealing with the difficult problems of to-day.

I shall have failed in my purpose if I have left my hearers under the impression that I am wedded to or pleading for any particular division of the wealth of the country. We hear much talk about abstractions called "capital" and "labour." The terms are convenient enough if we do not let ourselves be deluded with the idea that they mean more than the sum of those who own the capital or supply the labour. Labour itself is a somewhat ambiguous term. Till comparatively recently the members of the 'labouring classes' so called thought it was synonymous with the man who laboured with his hands, and 'the horny-handed son of toil' was contrasted with 'the pampered minion of luxury.' The Labour Party itself has been fain to enlarge its definition so as to include all those who 'labour by hand or brain.' If we could be brought to see that there is no hard-and-fast division of men and women into the one or other of these classes, but that nearly all of us belong to both, a good deal of our present trouble would disappear. Not one of us, if independent of capital, the most poverty-stricken member of the community relies as implicitly on it as the richest among us. To talk of the 'abolition of capital' is to use a form of words which is absolutely meaningless. What most people who use them really mean is one or other of two things, sometimes both at the same time—either that the capital is in the wrong hands and that it should not be held in the way or to the amount which is at present the case, or that the division of the joint product of capital and industry is defective, and should be altered.

It will be seen that these are two quite different questions, and call for consideration on quite different lines. If great aggregations of wealth are deemed undesirable the community may take means to limit the amount held by any one man. But where the line should be drawn is a very difficult problem. It would be easy to show that human progress has depended on the thrift of our ancestors, and to prove that, in like manner, our future progress depends on a continuance of this policy of not spending on the enjoyment of the hour all the product of our industry. Implicitly this assumption is made by every one who criticises the condition of our various industries in this country and compares them unfavourably with those of other lands. They are, in fact, saying that our railways or mines or steel works have been starved. Yet, with almost the same breath, they complain that the men engaged have been insufficiently remunerated for their labour. I see great difficulty in saying no man's fortune shall exceed some given sum, and even in saying no man shall bequeath to his survivors more than some very moderate amount. In either case I should fear endangering that building up of capital which, however it may be divided, is essential to our national progress.

When we come to the division of the joint product of industry and capital other considerations become apparent. The question at once arises whether any other division would have been possible in the past, or could be accomplished in the future, without great changes in the way in which the product arises.

Reference has already been made to my own examination of this matter, which leaves me in no doubt that any considerable increase of the part of labour would have left the share of capital so small as to have stifled enterprise.

This does not mean that large fortunes may not have been made by those whose skill and industry and enterprise enabled them to seize the advantages presented to them. If an illustration may be drawn from the history of my own firm, I may say that over and over again have we embarked on undertakings which we had in the end to abandon as unprofitable. Those who were, in fact, our co-adventurers, the men whom we employed, ran no risk. They were paid the sums to which they were entitled as the result of bargaining in an open market. The wages paid were those ruling in the district. Such machinery or other supplies as were needed were bought as cheaply as was possible. We took all the risk, and bore all the loss which often resulted. We had no qualms about taking the profit when any ensued. The capital which by incessant industry and application has been thus accumulated has served to provide employment for the sons and grandsons and remoter descendants of those who first worked for my father and his brothers seventy-five years ago this very year.

Those who cry out against capital overlook the fact that in modern industries no man can be set to work except by means of a capital sum first found for the purpose. In the industries I know best something over £200 is needed to put a man to work. The population of this country increases at the rate of about 1 per cent. per annum. This means that for every 1,000 men to whom employment is being given about ten youths are ready to be set to work each year, and something over £2,000 must be found year by year to give them employment. It is not an unreasonable boast for a captain of industry to say that in this respect he has performed his duty to the community.

One further point must be made. Men see some great enterprise (and the railways will serve very well as an example), and look upon it as a capitalist organisation. But when the circumstances are examined it is found that it consists of a multitude of small holdings, and comparatively few of large amount. In the North-Eastern Railway something like 60,000 shareholders hold the 83 million pounds of capital of various denominations—say, on the average, some £1,600 each. Consider the widespread distress which would be caused if the income from the sum were to cease.

I have made a similar calculation for a large colliery undertaking in which I am interested, with the following result. The capital in shares and debentures is about £1,300,000. There are just over 1,800 shareholders. We employ 5,500 men. Each shareholder therefore provides employment for about three men and holds on the average £725. Before long we shall require further capital. We see our way to enlarge our operations and so to provide employment near to their homes for the 50 to 60 youths who, each year, grow to manhood and need productive employment if they are not to become burdens on the community. We hope our 1,800 shareholders will have laid by enough to provide the £12,000 a year which is necessary for this purpose. We are assuming they or someone will provide it, for we are using our resources (reserves and depreciation funds) in this way, and shortly it will be incumbent on us to fund this obligation and add it to our capital.

Let us be very cautious how we interfere lest we produce evils infinitely greater than those which it is sought to remove. What, for example, will those 50 to 60 young men say, if we reply to their applications to be given work with us, that all our resources have been used in paying additional wages, and we have accordingly been obliged to let our plant deteriorate instead of adding to it and that, far from offering additional employment, we fear we may have to dismiss men to whom we at present give work?

We are thus brought to the last subject which I desire to consider with you—the widespread tendency towards what is somewhat vaguely called Nationalisation. It may be questioned whether any large number of people have very clear ideas what is meant by the term.

Let us assume for the present purpose that it signifies that the State shall become the owner of any enterprise which is nationalised—as it owns the business—the Post Office, the Telegraphs and the Telephones. Let us ask what advantage will be gained by the assumption of ownership. A centralised

management even of so simple a business as that of collecting and distributing letters and parcels has not been an unqualified success. Where the business is more complicated, as in the other examples, the success has been even less conspicuous. What reason have we to hope then in such intricate matters as the Railways or the Mines better results will follow?

The incentive of individual gain will have disappeared and with it the readiness to accept such risks as those to which reference has already been made. We may easily find that the developments needed to find employment for our young people is not forthcoming, for without such risks being taken no growth of employment will take place. Unless I am much mistaken a great temptation will be put before politicians to make concessions to the huge army of voters who will be in the direct employment of the Government.

The experience of these five years has failed to teach the lesson that you cannot touch one branch of labour without affecting all others. An advance of wages given to one section will inevitably be demanded by all others. The result will be prejudicial to the whole community. As regards each individual trade it may be of little moment what we call the wages, the wage earner has in the past obtained a certain (very large) percentage of the whole value of the product; whether it is called one hundred or two hundred is of little moment unless indeed he can succeed in obtaining for himself higher rates of wage than those prevailing in other industries. But as regards international trade the position may be very different, and we may find ourselves shut out of foreign markets because our wages are made artificially high, just as we should be excluded if, for example, the shipowners could compel us to pay inordinate freights on some indispensable raw material like cotton.

A cure will speedily come, but it may come after great suffering has been inflicted on the whole community. Parliament can easily impose on the employer, whether a private individual or the State, the payment of a certain wage if a man is employed, but one thing it cannot do and that is compel the employment of the man at a wage which the price of the article he produces will not suffice to pay. The man will remain unemployed. That is the drastic remedy which economic law imposes. We may escape it by making up from some other source the deficiency if we insist on having the article and refuse to pay the cost. But this remedy is only applicable to some small part of our total product. When we come to such industries as those now talked of it is impossible. We must make the industry self-contained.

The hope that by transferring its ownership to the State from the individual will enable us to pay more is foredoomed to disappointment. There is indeed one—and only one—way in which higher wages can be obtained. That is by a greater product per unit of capital and per unit of wage. If an article now produced at a combined capital and labour cost of, say, 100 can by improved methods be produced at, say, 80 and still sold for 100, and if capital is still satisfied with its former share, then the whole of the extra 20 will come to labour. Long experience teaches me that it is in this way that wages have advanced in the past and that in this way alone can they be further increased in the future.

But it may be said that those most concerned are not striving alone, or even chiefly, for higher wages, but desire to participate in the management and to bear their part in deciding the questions of policy which up to now have been in the hands of the employers. To this no fundamental objection can be raised. The more completely the men engaged in any enterprise understand it the better it will probably be for the whole. But large questions of policy require knowledge and appreciation of circumstances which can with difficulty be acquired by persons whose life is necessarily passed in quite other surroundings. That the fullest information should be given to the persons in question cannot be denied. The claim to deal with matters of management lying quite beyond their competence cannot be conceded. The final impulse comes from one mind which cannot divest itself of its responsibility nor exercise it under such conditions as those suggested would impose.

In the brief compass of an hour I have sought to describe the difficult situation in which we are placed and to enumerate some of the intricate economic and social problems which call for solution. It is impossible to view the future

without apprehension. A universal unrest pervades the world. This had indeed already become apparent before 1914. The war has exacerbated the symptoms which were already sufficiently menacing. Remedies by legislation had been applied here and elsewhere without success. In the nineteenth century the political emancipation of the inhabitants of this country was gradually effected. By the end of it freedom had been practically won. The great changes which occurred in the political condition of the country as it was before 1832 and as it became by the end of the century had been brought about with relatively little trouble. It is not surprising that this should have led to the conclusion that economic changes could be effected with equal ease. Perhaps the confusion which we continually observe between a 'law' imposed by the will of a legislature and a 'law of Nature,' so called, is responsible for this confusion. Parliament, we are told, can do anything except 'make it rain or hold up.' It may perhaps even effect this by enacting that under certain circumstances it shall be 'deemed' to rain or hold up, as the case may be. But the most ardent believer in the power of legislation to bring about important changes will not be prepared to deny that, whatever the legislators may say, he who goes out in the rain will get wet.

Having gained political freedom comparatively easily people seem to have thought economic freedom would be got with equal facility. We have had numerous instances of this on which it is unnecessary to dwell. Concessions have been made by which, apparently, life was made much easier for certain people. But the fund out of which these concessions were to come has not been increased. Many of them, though not so intended, had the effect of positively lessening that total. In a perfect world it ought not to have had this effect, but, human nature being as it is, it was easy to foresee the result. It could have been foretold that a minimum wage established by law would sooner or later reduce the output of the man paid by piece. It had that effect on the coal miners at a very early date after its enactment.

The demand for higher wages without corresponding increased output was causing anxiety before the outbreak of war. The inordinate expenditure which the war brought with it seemed to justify the contention of the workmen that the claims they had put forward would easily have been met in the past and must be conceded when things became normal again. It was forgotten that all thought of economic production had ceased. We were living, not on the earnings of the year, but on credit raised on our expectations of the future. In the past this course was also pursued, but (as has already been pointed out) in very different circumstances, for the capital thus created was calculated to yield an adequate return to the persons interested.

It is to be feared that the limitations imposed are not appreciated by those who will be most affected. The Legislature reduces hours from eight to seven in the coal mines. The miner claims that his earnings shall not suffer. Circumstances make it difficult for him to get as much coal in seven hours as in eight even if he were willing. It is hard to see how we can escape the conclusion that the coal will cost more. The coal owner alleges that he is unable to pay the higher cost except by obtaining a higher price.

None of the remedies proposed touches the difficulty. We must obtain a larger product if we are to have more to divide. Restrictions in output, whether produced by the act of the Legislature, the will of the worker or (let us add) the hindrance of a tariff, will fail to effect this. None of the short cuts now proposed will lead us to our goal. Can we convince those most deeply interested of the truth of this? The task is not an easy one, for promises without end are made to accomplish what is desired without pursuing the patient and laborious course which alone can lead to a happy solution. For my part I rely on the common sense of my fellow countrymen. The speedy abolition of all artificial prices by which we shall get to know the real cost of what we buy will be a great help. We may hope that on this will follow an earnest desire on the part of all to do their best for the commonweal—convinced that on this intelligent altruism we are best serving our own ends. A better division of industry would ensue. The net result would be a happy and contented nation, in which the efforts of each would be more guided by the common welfare than by the selfish desire for the advantage of the individual.

Perhaps employers and employed alike will come to see how greatly a strike or lock-out militates against the true interests of both. Perhaps the employed will learn that the party in the State to which they belong suffers much more than any other by these occurrences. Is it too sanguine to hope that, as Professor Cannan says, we may drop 'the notion that trade is a kind of war, whereas it ought to be regarded as co-operation between friends, none the less friendly because they bargain and even haggle.' [1]

None of these things can be accomplished by Acts of Parliament. Statutory prices and statutory hours offer no solution—rather increase the evil than lessen it. There is no Royal Road by which we can travel to a solution. We must by patience and mutual forbearance seek to alter the present hostile attitude. We may frankly accept Professor Cannan's opinion 'that the economic organisation of the nineteenth and early twentieth centuries will not endure for ever, but will be gradually replaced by something else more suitable for its own day and generation.' [2]

Let all parties in the State lend themselves to this change, in which again, to quote Professor Cannan: 'Free associations of free men able to go out and come in as each pleased, would voluntarily give service for service, irrespective of domicile and nationality.' This is a change which we may agree with him in thinking more 'desirable than any restoration of the feudal system basing economic organisation on the territory of the lord, even if the personal lord of the Middle Ages is replaced by a Parliament elected by universal suffrage and proportional representation.' [3]

PUBLIC EXPENDITURE.

Twelve Weeks before the Armistice.

Period Ended—	Supply Services	Interest on War Debt	Total Expenditure
	£	£	£
August 24 . .	40,375,000	708,661	41,473,661
„ 31 . .	51,939,848	3,059,437	55,169,201
September 7 . .	44,130,000	813,337	45,098,369
„ 14 . .	50,317,042	845,986	51,526,856
„ 21 . .	40,670,000	828,506	42,119,686
„ 28 . .	42,402,700	2,974,400	46,780,500
October 5 . .	38,190,000	20,804,188	61,410,931
„ 12 . .	36,105,554	2,904,670	39,729,851
„ 19 . .	49,319,000	2,136,672	51,755,672
„ 26 . .	44,355,000	887,398	45,542,398
November 2 . .	47,575,326	1,218,924	49,104,416
„ 9 . .	54,569,871	926,003	55,806,254
	539,949,341	38,108,182	585,517,795

[1] Coal Nationalisation, p. 25.

[2] *Ibid.*

[3] *Ibid.*

Twelve Weeks After the Armistice.

Period Ended—	Supply Services	Interest on War Debt	Total Expenditure
	£	£	£
November 23 . .	30,250,000	16,303,458	46,553,458
,, 30 . .	39,413,243	819,929	40,428,336
December 7 . .	42,100,000	49,114,929	91,920,829
,, 14 . .	42,459,404	6,322,606	49,224,649
,, 21 . .	51,571,000	1,340,988	53,003,201
,, 31 . .	60,256,704	2,705,130	64,517,390
January 4 . .	22,600,000	834,265	24,874,084
,, 11 . .	26,141,098	1,098,690	28,294,788
,, 18 . .	38,000,000	689,592	38,960,389
,, 25 . .	31,847,000	573,109	32,420,109
February 1 . .	49,914,702	788,404	51,153,272
,, 8 . .	41,625,296	1,097,589	42,733,265
	...	...	564,083,770

The following Papers were then read :

1. *The National Alliance of Employers and Employed.* *By* the Right Hon. F. Huth Jackson.

In the autumn of 1916 a group of three employers and four trade unionists met to discuss the probable effect which war conditions would have on our industrial system. These seven men, realising the gravity of the problems which already were confronting the country, and visualising the still greater problems which the future had in store, took what was then the somewhat adventurous step of initiating a movement whose whole foundation was unity of effort on the part of employers and trade unions on a basis of frankness, comradeship, and good-will.

To that small and unpretentious gathering is to be traced, not only the National Alliance of Employers and Employed, which was the immediate result, but the whole of the great movement towards co-operative effort which now promises to remould our industrial life and which recently led to the calling by the Government of the National Industrial Conference, and the setting up of the National Joint Industrial Council.

From the commencement we have realised that in industrial development there could be no middle course. The old enemies, Capital and Labour, had either to plunge into more bitter and more widespread strife or to discover a common ground on which they could get together and for themselves work out the lines of harmonious progress. In the face of innumerable difficulties, and in spite of misunderstandings and misrepresentations, the National Alliance has discovered that common ground, and to-day, in thirty of the most important industrial districts in the country, Joint Area Committees (on which, as on the central body, employers and trade unionists are represented in equal numbers) are working in harmony and understanding, not only for the peaceful

reorganisation of industry as such, but for the development of higher social conditions and the raising of the standards of life.

This is just where the work of the National Alliance differs in extent from that of Whitley Committees, and even from that of the organisation to be set up in connection with the National Joint Industrial Council. We take the view that, essential though it may be, it is not sufficient for employers and employed in any one particular industry to co-operate merely for the improvement of the commercial and the working conditions in that industry. The wider problem is not solved merely by settling hours of labour, rates of pay, amounts of output, &c., and leaving such questions as the provision of healthy home surroundings, educational opportunities, recreational facilities, &c., to take care of themselves. The machinery of the National Alliance is designed not only to bring the employers and employed of a given industry together for the settlement of their own especial problems, but also to link up the employers and employed of all industries in a particular area in a joint endeavour to improve the general conditions in that area.

The work which the National Alliance has taken in hand is a great and difficult one, but on its accomplishment depends the future of our country. The evil centuries of hatred and struggle between the forces of Capital and Labour have built high and wide their barriers of antagonism and dark mistrust. They cannot be swept away in a day, but the experience of the National Alliance has shown that on each side there is an increasing number of earnest, thoughtful, far-seeing men who are realising the errors of the past and who are willing to join in a great national fellowship for the security of the future.

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2. *Price-fixing, with special reference to Australian experience.* *By the* Hon. Sir Charles G. Wade.[1]

The demand for fixing prices has arisen from two causes :—

1. The continuous rise in wages has led to a corresponding addition to the cost of production and the cost of living. This increase in turn has led to demands for still higher wages; and so a vicious circle is established until at last the workers have demanded that whilst the right to further increases of wages shall not be curtailed a limit shall be placed upon the consequent cost of living.

2. The dislocation, during the war, of manufacture and the means of transport, and the commandeering of material, created a scarcity in certain commodities. The scarcity led to an increase in prices, and some commodities became the subject of a monopoly.

Some people claimed that this rise in prices was but temporary, that the law of supply and demand would eventually adjust the trouble automatically; but where a commodity is 'cornered' this is no answer, and some drastic measure of control is essential. Hence the claim for compulsory fixing of prices; at all events whilst the war lasted.

This policy met with some success during the war, but must not be taken as a guide for peace conditions.

During the war producers were less restive; all classes were animated by patriotic feelings; workers made greater efforts, the consumer submitted to hardships and high prices without much protest. Further, although maximum prices were fixed yet it is generally believed that they were fixed so high as to dissuade the profiteer from offering opposition.

What would be the result in peace time where private gain is allowed to operate?

1. If the price fixed for any one commodity ceases to be profitable, the efforts of the producers will be directed into another channel which yields more gain. Thus a real scarcity may be created.

[1] See Sir C. G. Wade, 'Price Fixing by Law,' in *Fortnightly Review*, November, 1919.

2. Further, if any one trade is controlled in respect of prices the same rule must be applied to every link in the chain of production. Otherwise an excessive price of any one factor may unduly raise the cost of the whole.

3. Again, investment of capital may be discouraged or capital sunk in existing operations may be withdrawn and placed on deposit. Thus a scarcity of commodities will be created.

The flow of capital cannot be controlled or the avenues of production be maintained on unprofitable lines under conditions of private enterprise.

Logically, the only effective policy is for the State to control the channels of production and to give orders which must be obeyed by producers. The State will own material and direct the channel and volume of production. This involves eventually the State control of all production, for if prices are fixed in Government-controlled establishments alone trade will be diverted to establishments that are privately owned.

In the next place, if the State is to avoid a glut in production and a loss to the taxpayer an estimate must be provided of all requirements; but whilst the total estimate may be stated, the individual, from a variety of causes, may exceed the maximum production expected from him. This would seem to involve a further control of each individual's output, and if applied to one trade must be applied to all in any way dependent upon it.

Thus we are forced into State Socialism and control of the means of production and distribution.

Nationalisation is impracticable. Is such a huge Civil Service possible? Can production be regulated on sound business lines? Can the management be freed from political pressure? Will it not lead to inefficiency of labour, reduced output, higher cost to the people, or losses to be made good by taxation?

The war experience in Great Britain in the direction of State control cannot be taken as a safe precedent. Experience is against Governmental compulsory price-fixing. An attempt was made during the French Revolution, but the result was to divert production to more profitable channels, to create a real scarcity, and cause privation to the people. In a few years a loud demand was heard to abandon the policy of fixing prices.

In New South Wales an effort was made in recent years to limit prices in respect of butter and wheat and hay. But the experience was the same as during the French Revolution. A real scarcity was created, and the Government was compelled to make good the shortage by purchases from overseas at a price which was greatly in excess of the maximum previously fixed for the article.

The true remedy lies in—

1. Public investigation of the costs of and profits from operations which are suspected of profiteering, by means of a tribunal of investigation with compulsory powers of extracting information and giving full publicity to the inquiry. Trusts and profiteers abhor the daylight. The public would learn who are the offenders and the fear of exposure would compel all producers to bring their prices to a figure which can be absolutely justified.

2. If the tribunal reports the prices of a commodity are excessive, this shall by statute be deemed to be *prima facie* evidence of an offence, involving a heavy fine. The defendant would be entitled to acquittal provided he can show (1) that such figures were not in fact unreasonable, bearing in mind the claims of workers, employers, and the general public; and (2) that they were not in fact detrimental to the public.

In this way competition may continue on normal lines. Any attempt to corner commodities would be countered first of all by public investigation; secondly, by public reprobation; and, thirdly, by heavy penalties if the first two methods failed. The dangers of trade being diverted would not arise. The experiments of State Socialism need not be risked.

WEDNESDAY, SEPTEMBER 10.

The following Papers were read :—

1. *Industrial Councils and their Possibilities. By* T. B. JOHNSTON, *J.P.*

2. *Transport Policy. By* W. M. ACWORTH.[1]

3. *The Value of Full and Accurate Statistics as shown under Emergency Conditions in the Transportation Service in France. By* Lieut.-Col. Sir J. GEORGE BEHARRELL, *D.S.O.*

Statistics have played a most important part in all our war activities. The intensive production, coupled with the highest efficiency, necessitated by war conditions, enforced the preparation of full and exact information.

Output of material, capacity of works, rate of manufacture, and progress of the various processes had to be carefully studied, so that all material came forward in balanced and adequate quantities. This was especially true of transportation operations in France. The requirements of the various components of track, rolling stock, workshop equipment, and personnel for all sections of the work had to be forecast and provided a considerable time ahead.

War conditions precluded the application of the ordinary financial test of the success of operations, but the shortage of men and material compelled economy and efficiency.

Transportation in France covered a variety of services :—

The equipment and operation of ports.

The provision and operation of craft for inland water transportation, and the construction and maintenance of necessary work on canals.

The construction and operation of standard gauge, metre gauge, and 60-centimetre railways.

The construction and maintenance of roads and *cours*.

The working of quarries.

With operations so diverse, and scattered over such a wide and varying field, complete supervision by the Director-General of Transportation was only possible by making the fullest use of the science of statistics.

The exceptional circumstances which prevailed rendered it imperative that statistics should be prepared quickly and given a wide and judicious circulation. In spite of the difficulties of communication over the wide area involved, it was possible to produce, not later than Tuesday evening, preliminary figures for the week ended midnight on the previous Friday, giving the result of the working of all services, *i.e.* four days for collection and compilation in respect to services extending from the ports at the base to light railways along the front. The circulation of statistics is most important; a considerable proportion of the success can be attributed to the interest and spirit of emulation which they created.

Under the new Transportation organisation the Director-General determined the kind of transportation to be provided. The General Staff communicated the plan of campaign, and the Director-General of Transportation decided—having regard to the available resources of men and material, and the traffic to be moved—whether new broad-gauge lines and railheads should be constructed, what use should be made of canals and whether distribution by 60-centimetre lines or lorries should be adopted. There was no hard-and-fast rule.

Statistics for each branch of the Service will be considered in some detail. The following indicates the units of efficiency employed. Figures illustrating the improvements effected will be quoted.

[1] See *National Review*, October, 1919.

Docks.

Regulation of traffic to avoid congestion of quays, achieved by preparation of programme showing :—

Tonnage of various traffics to be dealt with.
Proportion of each traffic allocated to each port.
Circulation of weekly statistics showing how allocation had been worked to.

Working of Ports.

Tonnage discharged per hour in port.
Tonnage handled per man per hour.
Ship days lost.

Broad Gauge Railways.

Construction.

Progress diagrams.
Percentage of earthwork and track completed.
Number of men employed.
Comparison with rate of progress essential to completion of work in specified time.

Operation

Record of rolling stock available.

Traffic working :—
- Kilometres per locomotive in steam per day.
- Hours per locomotive in steam per day.
- Number of loaded wagons per train.
- Average haul.
- Loaded wagon kilometres per effective personnel employed.
- Fuel consumption.

Wagon user :—
- Wagons standing under load at depôts.
- Detention at railhead :—
  - Time before unloading.
  - Time occupied in unloading.
  - Time from completion of discharge to return of train.

Repairs.

Output of shops in relation to personnel employed.
Reduction in percentage of locomotives and wagons out of traffic.

Light Railways.

Construction and Operation.

Length of line.
Men per mile of track maintained.
Tons conveyed.
Ton-miles worked.
Power units in service per route mile.
Wagon units in service per route mile.
Ton-miles per power unit in service per day.
Tons per wagon unit in service per day.
Tons per loaded wagon unit trip.
Average length of loaded wagon trip.
Number of loaded wagon miles per route mile per day.
Loaded wagon miles per effective personnel per day.
Loaded wagon miles per power unit in service per day.
Loaded wagon miles per wagon unit in service per day.
Consumption of fuel.

Repairs.

Output of shops in relation to personnel employed.
Reduction in percentage of locomotives and wagons out of traffic.

Inland Waterways.

Traffic handled.
Ton-miles worked.

Roads.

Total mileage maintained by British Army.
Area of new roads and *cours* constructed.
Area of existing roads and *cours* reconstructed.
Area of roads and *cours* re-surfaced.
Material used and number of men employed.
Plant: percentage under repair.
Working of quarries:—
Total output.
Output of stone per man.
Working of lorries conveying road stone, etc.: Ton-miles per lorry per day.

Personnel Employed.

Percentage skilled, unskilled, and non-effective.

Joint Discussion with Section L on Business in relation to Education.
See Section L, p. 355.

THURSDAY, SEPTEMBER 11.

Joint Meeting with Section I and Subsection of Psychology.
See Section I, p. 308.

FRIDAY, SEPTEMBER 12.

The following Reports and Papers were read:—

1. *Report of Committee on Replacement of Men by Women in Industry.*

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2. *Inter-imperial Communications.* *By* Sir Charles Bright.

The war has produced a shortage of communicating links with much telegraphic congestion and resultant delays that need to be considered with a view to remedy.

Moreover, the increased tendency and need of communicating with other branches of the Empire calls for special and early action in political and trade interests.

The All-Red Cable Route requires to be rendered a complete reality as soon as maybe, including a new absolutely British Atlantic Cable and a duplication of the Imperial Pacific line, with satisfactory independent land line connection between the two.

It is conceivable that national and imperial interests can only be adequately provided by the State controlling at least one complete cable to all points of the British Empire, supplemented by an All-British Wireless Chain. The whole should be run at a single and distinctly low imperial tariff, common to all and independent of distance.

It is considered by the author that inter-imperial communication should be mainly regarded from the standpoint of

1. Its political value;
2. For defence purposes; and
3. As a means for developing inter-imperial trade and so helping to increase production.

We require to note American cable and wireless enterprise in this direction. The recently established Telegraph Communications Board, first urged by the author seventeen years ago, is intended for generally controlling and developing inter-imperial telegraphic and aerial communication in national and public interests. By this scheme all of the several Government Departments concerned (strategic as well as civil) are represented by delegates who meet periodically to discuss and settle all matters germane to the subject. This should do much towards improving the previously existing arrangements by which the Post Office alone represented the Government.

Besides increased cable and wireless facilities being necessary and the war devastations made good, it is highly desirable that improved methods of message condensation be introduced so as to get the best results from existing facilities.

The field open to inter-imperial air communication is considerable; air organisation and air routes are among the important questions of the day, while the rationing of all aerial mail communications should be insisted upon.

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3. *The Special Taxation of Business Profits in relation to the Present Position of National Finance.* *By* Dr. J. C. Stamp, *C.B.E.*[1]

On the present facts, permanent revenue on the existing basis will fail to meet the permanent expenditure by a large margin, variously estimated at from 50 to 150 million pounds, and probably not actually far from the latter figure. Three alternative ways of meeting this deficit are presented :—(1) A substantial increase of income and supertax rates; (2) a levy on capital; (3) the taxation of business profits. The increase in income tax would entail either such rates on the higher incomes as might seriously hinder the accumulation of capital, or such a considerable addition to the burden upon working-class incomes as would make the proposition a serious one from a political point of view. The second contains such elements of difficulty as to make it probable that it would fail to commend itself as fair and just to more than a very small proportion of the payers—a serious outlook for any impost. Those economists who support it do so distinctly upon the basis of a commutation of future high rates of income tax, but the proposal receives its main impetus from those who for themselves give no guarantee either of non-repetition, or of a relaxation of future taxation, but rather indicate that they propose to be free to impose high taxation for new social objects. Moreover, there is a failure to do justice as between people whose fortunes have changed, and injustices may arise through expedients to make the tax workable in practice, which so far has been an aspect but superficially dealt with. The levy would fall alike upon well-gotten gains saved up as the result of pure thrift and the gains of profiteering. It would do nothing towards taking special toll of profiteering elements in future trading. Just as graduated taxation reaches the differences of ability to pay according to the *amount* of individual income, so something is wanted to search out those classes of gain which serve no functional purpose in that they are a rental surplus the taxation of which has no evil effects upon supply. The plea that the stiffer taxation of higher incomes automatically achieves this is so often invalid as to be of little worth as a main principle. These gains must be 'tapped' higher up the stream of distribution. The basis of the old Excess Profits Duty was special ability of businesses measured by their success compared with their *own* past history before the war. This endowment of the successful would be unsuitable for permanent application. But the method tried in the United States and Canada, suitably modified, has features of permanent value. It submits

[1] See *Economic Journal*, December, 1919.

businesses to a reasonable and fair general comparison. Graduated gently from the lower excess above a 'normal' rate of interest on capital, it reaches a high rate upon very high rates of earnings on capital. Thus it does not discourage trade nor lead specially to evasion. Its practical difficulties are no greater than those attaching to the rival alternatives. Its basis of principle, though new, is clear: certain economic units through a fortunate set of circumstances get a special 'pull' which yields supernormal profit, that has a high capacity for bearing taxation without ill-effects. It is an impersonal faculty, which has hitherto not been realised as a basis for taxation, in an attempt to reach more directly the differential non-functional elements in profit and income.

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4. *The Gold Standard.* *By* R. G. Hawtrey.

The monetary standard regulates the value of the monetary unit, or the unit for the measurement of debts. The function of the standard is to maintain the stability of the system of debts based on the unit, that is to say, to ensure that the unit represents approximately the same command over wealth throughout the currency of the debt. As the relative values of different kinds of wealth vary, an ideal standard is not theoretically possible. The gold standard is a rough and ready solution of the problem by fixing the price of one commodity. Debts are made payable in gold, or alternatively a paper currency is so regulated that the monetary unit is in fact equivalent to a prescribed quantity of gold.

In 1914 the gold standard was established nearly everywhere, except in China. Gold and credit were interchangeable. But this system has been destroyed by the war. Excessive creations of paper money and credit have depreciated the monetary units, have driven gold out of circulation, and have put an end to the interchangeability of credit and gold. During the war there has been no world market for gold; now that the market is reviving in America, whither the superfluous gold displaced from circulation in Europe has flowed, the value of gold in commodities is found to have fallen heavily. The existence of large stocks of gold in use as currency, which may be released and flood the market, is a source of instability in the value of gold. In considering the future monetary standard, we have to deal both with the depreciation of existing monetary units in comparison with gold, and with the loss of value of gold itself.

To restore a depreciated unit to its nominal gold value requires a measure of deflation. Deflation, which is a reversal of the process of inflation, must mean a decrease in the aggregate of money incomes. This is effected by a contraction of credit, and especially by a high rate of interest on short-period borrowings. A high rate of interest deters traders from holding stocks of commodities or securities. It hastens sales and retards purchases, and brings about a fall of prices and a contraction in the volume of credit. The fear of the consequent depression of trade makes the business community hostile to any drastic measure of deflation, and unemployment and falling wages are likely to create further difficulties.

Other methods of re-establishing a gold standard are, *first*, the immediate re-introduction of the old gold unit and the reduction of the current value of the depreciated paper below its face value, or, *secondly*, the reduction of the gold value of the monetary unit below its former nominal value. The first gives rise to serious difficulties owing to the sudden increase in the burden of debts. Both methods are open to the imputation that public faith is not kept.

If the use of gold as money is restored either by deflation or by a manipulation of the currency, the result may be a revival of the former demand for gold, which would intensify all the difficulties. In particular it would cause grave embarrassment by increasing the burden of national debts. If the embarrassments of any country become so severe that its credit system breaks down, the natural consequence will be a relapse into depreciation, and there may follow a complete loss of confidence in the paper currency and a disregard of the legal tender laws. The resulting demand for metallic currency would raise the world value of gold in commodities, and threaten the gold standard elsewhere.

To gain the advantages of an unvarying gold currency unit, the demand for gold as currency must be kept as steady as possible. If the demand is not to

increase, there must be a great economy in the use of gold as compared with what prevailed before the war. This can be managed by means of the gold exchange standard. But there must be some method for preventing the economy of gold, which this system makes possible, from further *diminishing* the currency demand for gold.

International co-operation is required, and this should be directed to stabilising the general level of prices as measured by index numbers, and to regulating the actual amount of note issue in each country. Provided the financially strong countries are included the international co-operation need not be universal. It can be started as soon as the Anglo-American exchange can be brought to par.

5. *Royal Commission on the Income Tax. Summary of Evidence submitted on behalf of the British Association by* Sir Edward Brabrook, *C.B. (Acting Chairman), and* J. E. Allen, *Hon. Sec. of Committees on 'Income Tax Reform' and 'The Effects of the War on Credit, Currency and Finance.'*

The Committee on War Finance, in its Reports for 1916 and 1917, referred to Income Tax, and suggested certain improvements directed towards making it fairer and more productive. But the Committee thought that the question was too large to be dealt with merely as one among several, and accordingly appointed a special Sub-Committee :

> 'To consider and report upon possible amendments to the law relating to income tax.'

The Sub-Committee prepared and circulated a *Questionnaire* and obtained opinions in reply from Accountants, Surveyors of Taxes, and others.

The Sub-Committee drew up, in 1918, an Interim Report, a copy of which was sent to the Chancellor of the Exchequer and the Secretary to the Treasury. The Committee has not arrived at a final Report, and therefore has not presented one to the Credit, Currency, and Finance Committee.

We are authorised to submit the following points as those on which there is a considerable amount of practical agreement in the Sub-Committee :

1. That the Income Tax is the fairest, cheapest, and most productive of all possible taxes.[1]

2. That the tax requires to be adjusted to the much-increased demand for Revenue.

3. That it is indefinitely elastic and can be made to produce as much Revenue as the citizens as a body think justifiable.

4. That if skilfully adjusted to the 'ability' of each tax-payer it imposes little real burden.

5. That a heavy Income Tax has a tendency to lower prices of commodities in general, just as an inflation of the currency increases them.

6. That a graduated Income Tax, unlike most (if not all) other taxes, makes for greater equality of spending power.

7. That the symmetry and equity of the tax are marred by 'steps and jumps' at arbitrary points in the scale of graduation.

8. That the tax should be intercepted at the time when the tax-payer receives his income.

9. That the existing machinery of the tax should be preserved as far as possible, and that the most useful and inexpensive machine in the tax-collecting plant—'collection at (or through) the source,' should be preserved and extended.

10. We are inclined to suggest that the tax on salaries, wages, and other periodical payments should be deducted by the person making the payments, at the time of payment.

11. That the employer or paymaster should be made the agent of the Inland Revenue in collecting the tax, and that he should be given some small remuneration for his trouble.

[1] We assume, of course, the existence of a constitutional Government; a despotic Government might use the Income Tax as an instrument of oppression.

12. That tax should be deducted at the lowest 'earned' rate from all wages and small salaries, and that in the case of regular payments such as wages or salaries the tax-payer's abatement and allowances should be taken into account at the time of deduction.

13. That in the case of 'unearned' income, deductions should *not* be made at the *highest* rate as at present, because only a small fraction of tax-payers are finally liable to pay this rate.

14. That in all arrangements and re-arrangements in connection with Income Tax the convenience of the tax-payer should be consulted before that of the tax-collector.

15. That the forms connected with assessment and collection should be stated in simple language, and that the tax-payer should be treated as a reasonable citizen who is willing to do his duty to the State when he knows what it is.

16. That no concession which makes a tax fairer should be refused by a Finance Minister on the ground that 'he cannot afford it.'

17. That all changes which make a tax system fairer make it more productive of Revenue.

18. We have considered various scales of graduation, but in the absence of knowledge as to the resulting produce we are not prepared to make a recommendation.

19. We think that any abatement which may be granted should be granted on all incomes whatever their amount.

20. The Committee was not unanimous on the question of 'earned' and 'unearned' incomes, but was inclined to dislike this kind of 'differentiation.' In particular we could not see why the income from a man's own savings should be treated as 'unearned.'

The following Paper was taken as read in the unavoidable absence of the author :—

6. *Unemployment in Eastern Canada.* *By* G. E. Jackson.

1. Ignorance of Canadian labour problems has in the past caused much avoidable distress. Seasonal changes in climate disturb industry in Canada far more than in England; and Canadian business, organised with a view to progressive expansion, as more labour and capital enter the country, may be dislocated when expansion ceases suddenly.

2. Lines of development have been decided partly by the tariff, but are not consciously moulded otherwise. The tariff has stimulated city growth. Immigrant farmers have also congregated in the cities, which before the war were considered disproportionately large.

3. Municipalities have attempted the relief of distress on no fixed principle, and in proportion as they give adequate relief attract from other cities their least desirable poor. Each is therefore tempted to shirk the recurring problem by passing on to cities in the neighbourhood its penniless unemployed non-residents. In times of stagnant trade the lot of recent immigrants is especially hard.

4. It was found that the proportion of unemployment among manufacturing operatives in Ontario, during the first half of 1914, was little less than 11%, and that the first effect of the war was a further decline in employment.

5. Decisive figures for mines and transportation agencies were not then secured; but the Federal Government now publishes a weekly statistical report on changes in the labour market, of considerable value.

6. Only recently has the State attempted organisation of the labour market. Till 1916 the foreign-born labourer was alternately helped and victimised by private employment agencies. Employment was often found for skilled artisans by their trade unions.

7. Since 1916 the Provincial Governments have instituted public employment agencies. Subsidies are paid by the Dominion Government, which co-ordinates exchanges by means of clearing houses.

8. Organised labour has refrained in Eastern Canada from encouraging revolutionary social changes. At one time suspicious of attempts by Provincial

Governments to maintain employment exchanges, now it endorses their accomplishment. It has for years condemned the private employment agencies, and is calling for their suppression.

9. Consistently believing that much unemployment in Canada results from disproportionate city growth, organised labour has also called for the State encouragement of land settlement, with financial aid and training. Recent federal legislation is in accord with these demands.

10. Although trade unions refuse to tolerate the coming of Asiatic labour, there is scant evidence of hostility to European immigration, on the ground that it causes unemployment. Nor is the view prevalent that it threatens the standard of life of Canadian workers. Circumstances have altered so as largely to invalidate the premises on which Walker built his famous argument.

11. Meanwhile, attention is directed in detail to methods of selecting and assimilating immigrants. This is no longer a domestic, but has become an Imperial problem, in which, however, Canada finds her freedom of action limited by the practical need of conforming to certain changes in American policy.

12. The breathing space afforded by the war has enabled the Dominion to strengthen its immigration service. Nevertheless, the great burden of unemployment will fall on immigrants for many years to come.

Section G.—ENGINEERING.

President of the Section.—Professor J. E. Petavel, D.Sc., F.R.S.

TUESDAY, SEPTEMBER 9.

The President delivered the following Address :—

During the last five years every resource of the Empire, moral, intellectual, and material, has been concentrated on one great task, now successfully achieved; and the present period marks the end of a gigantic military struggle and the beginning of a new social era.

I.—*Engineering and Science during the War.*

To summarise adequately the part played by engineering in the war would constitute a task far beyond the power of the writer or the scope of the present address. Now, as in the past, the fate of nations in war or peace is primarily determined by moral, intellectual, and physical attributes; but, under modern conditions, these forces can find efficient application, only through the agency of science and engineering.

A large army depends for its subsistence and equipment on the combined effort of every branch of human activity; and every productive industry, when organised on a large scale, is in turn dependent upon the engineer.

Before the end of the war this country had become transformed into one vast factory, every department of which required the services of trained engineers. Every member of this section has contributed his own share to the task, and our programme includes papers giving detailed accounts of several branches of the work.

It is fitting, therefore, that I should restrict myself to a mere outline of some of the more outstanding facts :—

The urgent necessity for an output of munitions vastly in excess of any previous production made centralisation and standardisation essential, and involved a complete revolution in workshop practice. The Ministry of Munitions was responsible for the formation of the required organisations, and guided the transformation of industrial conditions, and, when the dilution of skilled labour became inevitable, the technical engineer designed the machinery and devised the methods which made efficient work possible.

Credit is due to the Unions for the concessions made; greater credit to the women for their enthusiastic response to the call and the steady output they maintained.

Munitions.—The Ministry of Munitions was created in May 1915, its early efforts being concentrated on the production of guns and shells. A year later the Ministry was in a position to meet the ever-increasing demands of the Army, and by 1918 a large reserve of munitions had been established, the expenditure being limited only by difficulties of transport at the Front. The maximum expenditure of ammunition was reached one day in October of that year, when 900,000 shells, weighing 40,000 tons, were fired. The total number of guns

manufactured during the war was 20,000, and over 200,000 machine guns had been delivered by November 1918.

The Ministry of Munitions took charge also of the production of aircraft, which were ultimately turned out at the rate of 4,000 per month; later the provision of motor transport was in addition placed under its control. Finally, our production of 'poison gas,' for which this Ministry was responsible, rose during the last few months of the war to several thousand tons a month, sufficient to make the Germans rue the day on which they had introduced this weapon into warfare.

Among the inventions which have had an influence on military operations I will mention only three as typical of three distinct classes:

Tanks were first used in 1916, and the results produced were greatly enhanced by the surprise created, and consequent moral effect, but the idea of an armoured chariot is as old as organised warfare. The problem of constructing a vehicle which could travel across the trackless and shell-pitted district which extended between the two armies remained to be solved. In the light of the experience gained with various types of tractors it was, however, clearly not insoluble, and credit is due to the man who had the courage to hazard a novel and important experiment. The resulting tank was the product of careful design and experiment, and the outcome of the co-operation of several engineers with special knowledge. Sound-ranging introduced the complex methods and delicate instruments of physical research into the trenches, and, against all precedents, proved them to be reliable and practical under the most adverse conditions. The Stokes gun, on the other hand, superseded all other trench mortars by simplicity of design of manufacture and convenience in handling; 20,000 of these guns were used during the war.

Transport.—On August 4, 1914, the Government assumed control of the railway systems in this country, but the working and management was left in the hands of the railway officials, and to them is due the smooth working of the lines during a long period of exceptional difficulty. British engineers, civil or military, have been responsible for the transport through France, and during the last two years of the war large numbers of engines were sent across the Channel and miles of track was taken up in England and relaid in France. Road transport was organised on an unprecedented scale, and 100,000 new vehicles were delivered. A network of narrow-gauge railways was carried right up to the trenches, and numerous new roads, railway lines, and bridges constructed. Railway construction formed an important factor in connection with the advances in Mesopotamia and Palestine; in the latter case the entire water supply had for a long period to be drawn from the Egyptian base through a specially laid pipe-line.

In France and elsewhere the armies were primarily dependent upon sea transport for their food and equipment. This service, organised by the Navy, culminated in the unique effort which brought American troops at the rate of 300,000 per month, and thus overbore the balance which for four years had been oscillating between defeat and victory.

Among the notable new departures the cross Channel train ferry and the portable steel bridges, principally of the Inglis type, should be specially mentioned.

Navy.—At the outbreak of war the Navy was ill-prepared with regard to anti-submarine defence and mining. The influence of the submarine on naval warfare had been under-estimated, and mines were regarded as a somewhat discreditable means of destruction; but during 1915 the depth-charge and the Paravane were developed by the naval experimental department at Portsmouth, and later thousands of these were brought into use. In principle the depth charge consists of a canister containing a large charge of explosive and a pistol actuated by an hydrostatic valve. The merit of the invention resides in the simplicity, safety, and reliability of the mechanism. In designing the Paravane the body was borrowed from a torpedo, and wings, rudder, and elevator from an aeroplane. The secret of the device lies in the stabilising mechanism, which enables it to keep its position when the ship is running at high speeds. The Paravane enabled most ships to pass unscathed through a mine-field, and in a slightly modified form it served to seek out and destroy submarines under the water.

Sound location proved to be one of the most valuable inventions developed

by the Board of Invention and Research. By its means the position of a submarine explosion off the coast of Belgium could be found within a few hundred yards by observers on the English coast; passing ships or submarines could also be identified and located. Sound locators were also used on board anti-submarine craft, but at the time of the armistice were for this purpose being superseded by other methods.

Mine construction, laying and sweeping formed the object of many successive improvements. Mines of special construction, which cannot be swept by ordinary means and which explode without actual contact, were used in large numbers in 1918, and were particularly effective against submarines. Various new types of oscillating mines were also developed.

Many of the newer fighting units of the Navy were designed for speeds far in excess of anything that had been previously contemplated; the attainment of the required horse-power was rendered possible by improvements in boiler construction, by the development of oil-firing, and by the invention of the geared turbine. At the present time the horse-power of some of the fastest destroyers equals that of any pre-war Dreadnought.

Numbers of strange craft were designed for special purposes. The monitor was used as a floating fortress, and ships without funnels or masts formed cruising aerodromes. The torpedo net was known to be ineffective as well as inconvenient, but some years elapsed before ships were rendered immune to torpedo attacks by a wide outer sheaf of resilient construction. Some protection was first given to mine-sweepers by fitting the vessels with a false prow; the newer mine-sweepers were rendered nearly unsinkable by the provision of numerous bulkheads. The submarine was developed with regard to size, range, and speed. The latest and perhaps the strangest craft was the submarine fitted with a heavy calibre gun which could be fired when all but the muzzle was submerged.

Aircraft.—The rapid progress and expansion of aeronautical science and construction is perhaps the most remarkable achievement of engineering during the war.

In 1909 Blériot flew the Channel. In 1910 Cody won the British Michelin Cup by a flight of 185 miles. The Royal Flying Corps was formed in 1912, and it was decided that the equipment should consist of seventy-two aeroplanes and two airships. The number of aeroplanes available in 1914 was under 200; the number ultimately required proved to be more than 3,000 per month. The aeroplanes which were sent out with the Expeditionary Force in 1914 had a maximum speed of some 80 miles per hour, a rate of climb at ground level of 300 or 400 ft. per minute; they were equipped with engines of 60 to 100 horse-power. In 1918 the fast machine had a maximum speed of 140 miles per hour, a rate of climb at ground level of 2,000 ft. per minute; single-seaters were fitted with engines of 200 to 300 horse-power, and the largest machines were equipped with a power plant developing over 1,300 horse-power. The maximum height attainable had increased from 5,000 to 25,000 ft.

The Atlantic flight has given the measure of the success achieved in the design of long-range bombing machines. Two types were evolved: the fast day bomber, capable of carrying a useful load of about 3,000 lb. at a speed of 130 miles an hour, and the night bomber with a larger load and slower speed. The largest aeroplane manufactured in numbers was the Handley Page V/1500, with a weight of 11 tons and a power plant of 1,300 horse-power. Three days before the armistice two of these machines stood fully equipped waiting for the order to start for Berlin. The largest bombs in use weighed over a ton, and during the war 8,000 tons of explosives were dropped on the enemy. The experience which they had gained in the construction of the high-powered engines required for airship work proved to be a valuable asset for the Germans. Initially also their rate of production, both of aeroplanes and engines, was far superior to ours, and, faced with the menace of otherwise being for a period deprived of machines, we were bound to continue the use of certain standardised types longer than was desirable.

The labour difficulty was overcome by the introduction of a large proportion of female labour, which proved to be very suitable for aeroplane manufacture, and especially for wing construction. The bulk production of aero-engines presented grave difficulties. Every part had to be made to close limits so as to

be interchangeable, and it was necessary to maintain the highest quality with the minimum amount of skilled labour. For a period the supply of magnetos was both inadequate and unsatisfactory. The Germans had acquired practically a monopoly in this direction, and it became essential for us to build up a new industry on the results of careful research and experiment. The fact that under these circumstances a total of eight million horse-power was produced during the last twelve months of the war represents one of the greatest achievements of engineering organisation.

Synchronised gun firing through the propeller was first brought into use by the enemy, and the success of the Fokker was due, not to superior design, but to this characteristic armament and to the relatively high engine power. On the other hand, throughout the war the only stable machines were British. For observation work, night flying, and flight in fog and cloud the advantages of a stable machine are obvious. On the other hand, instability, inasmuch as it favours rapid and unexpected manœuvres, was for a time regarded as an advantage in aerial fighting, but later experience proved that a well-designed aeroplane could be made stable and yet remain quick and light on the controls.

Seaworthiness, no less than air-worthiness, is required of the seaplane, and this implies a machine of considerable size and weight. Most of the best seaplanes in use in 1918 had a total weight of four or five tons each, a speed of nearly 100 miles, and engines of about 700 horse-power.

The machines used by the special aeroplane ships were principally small fast scouts, but one type was of sufficient size to carry an 18 in. torpedo. In 1918 seventy aeroplanes were carried by the fleet as part of the regular equipment.

Airships proved to be of great importance in connection with naval work. The smaller non-rigids were used for patrol duty along the coast and convoy service, and by their means a submarine could be detected and attacked while still at a considerable distance below the surface. The success achieved was extensive, and ships convoyed by airships were practically immune from submarine attack. The larger non-rigids served as scouts in naval operations.

The SSZ had a speed of 50 miles and a gross lift of about 2 tons; the North Sea type a lift of 11 tons and a speed of 60 miles.

Compared with the achievements in other directions the record of British work in connection with the development of rigid airships is not entirely satisfactory. In this field, where consistent policy and firmness of purpose were essential, the Admiralty vacillated strangely. The *May-fly*, constructed at Barrow in 1910, was admittedly an experiment, and although an accident ended her career after the first few mooring tests, she had already served her purpose in providing the experience and data necessary for a more perfect construction. Nothing further was done, however, until after the war had started.

In Germany, on the other hand, painstaking plodding had built up success on the ruins of a dozen failures.

Improvements in the rate of climb of aeroplanes and the invention of the incendiary bullet brought an end to the effectiveness of the Zeppelin as a bomber, but as a scout in long range naval operations its influence remained considerable, and the recent successful journey of R34 indicates the possibilities of the rigid airship in times of peace. The useful load increases rapidly with size, and a ship 15 per cent. larger than R34 in linear dimensions could have carried 100 people to America.

What is popularly known as an invention, or an idea of revolutionary importance emanating from one person, has played relatively little part in the recent development of aeronautics. Success has been due to systematic investigation and to the combined effort of many scientific workers, trained designers, and practical constructors. With some exceptions the same holds true in the case of engine construction. Inventions there have been, 8,000 are duly recorded in the files of the Air Inventions Committee, but equipment and armament and accessories appear to have offered most scope for brilliant new departures.

Several inventions notably influenced the course of the war. The successful manufacture of incendiary bullets put an end to the Zeppelin raids, tracer bullets increased the accuracy of aim, and synchronising gear made it possible to fire through the propeller at the rate of nearly 1,000 rounds per minute. A satisfactory self-sealing petrol tank was manufactured after many unsuccessful attempts, and greatly diminished the risk of fire. Much ingenuity was displayed in con-

nection with bomb sighting and navigational instruments. Wireless telephone and directional wireless were introduced. A reliable turn indicator and improved compass made accurate navigation through clouds possible. Armoured aeroplanes were constructed; special machines were also designed for carrying 37 mm. quick-firing guns for use at the Front and against submarines; these guns fired a 1½ lb. high explosive shell.

The increased efficiency of the anti-aircraft artillery and the high rate of climb of the defending machines put a check on daylight aeroplane raids, while at night and in mist both searchlights and guns could be trained on the enemy even if invisible by means of sound directors. A screen of kite-balloons supporting nets formed part of the night defences of London, and justified its existence by the moral effect produced on the enemy pilots.

The use of airships near the fighting zone or within reach of enemy aeroplanes was impossible owing to the inflammable nature of the gas they contained, and in spite of all precautions the loss in kite-balloons was serious. The proposal to replace the hydrogen by helium came from a member of the Board of Invention and Research, and in 1915 experiments were started with a view to the ultimate production of several million cubic feet per month. The boldness of the idea is best emphasised by the fact that at that time it took weeks to obtain the few cubic inches of gas required for the preliminary permeability tests. Progress was accelerated when America came into the war, and at the time of the armistice a supply of 350,000 cubic feet per week was ensured.

The above outline of engineering activities during the war is both incomplete and imperfect. It may, however, serve to emphasise and illustrate the two features which characterised the period and made victory possible.

The first is: Large production, obtained by organisation, standardisation, and co-operation.

The second is: Rapid progress resulting from the stimulus to research and invention and the immediate application of the results obtained.

The required organisation did not arise as a natural development of the pre-war industrial activity: it was called into being by dire necessity and applied with grim determination. Before the war the British nation was anti-militarist, non-scientific, and strongly individualistic. To achieve victory the nation accepted universal conscription, and submitted to the mixture of Socialism and tyranny which necessity dictated. Under extreme pressure, scientific knowledge, technical skill, industrial ability, military and naval experience welded into a homogeneous and efficient organisation.

It is easy to disparage the effort or to point to defects, large or small, which tarnish the record, but the fact remains that, whereas in 1914 we were inferior to the enemy in every military asset except moral courage, in 1918 victory came as the result of mastery in practically all the thousand factors on which modern warfare depends.

The organisation involved the direct control of food, every essential raw material, shipping, and transport; further, under the cloak of various euphemisms, it involved the indirect control of all available capital and labour. The capitalist was granted the privilege of receiving and paying the interest on the money required. High wages and the Military Conscription Act ensured an adequate supply of labour in the factories. And these things came to pass, not by tyrannical order of an all-powerful Government, but by the force of a great idea working within the nation.

II.—Industrial and Economic Reconstruction.

The peace declaration is the opening of a new act in the world's greatest drama, and the events of the next few years will decide the fate of many generations. The future is always the logical sequence of the past; it is the present which gives direction to the forces which are acting in virtue of the ideals which are operative. The world is emerging from a furnace, and the rigid constitution of civilisation, for a moment plastic, will harden in the mould we form. It is, therefore, the duty of each one of us to attempt to understand the transformation which is going on, and influence it in the right direction.

The principal feature of the day is the insistent craving for better and easier conditions of life; in popular language this is quite inaccurately expressed by a demand for higher wages and less work. The two aims are far from identical; in fact, a little consideration will show that in some respects they are contradictory.

The total remuneration received by a nation is measured by its production, and this law cannot be alterated or affected by legislation or revolution. On the other hand, the share received by a class or an individual is capable of adjustment within certain limits. Thus any class may increase its remuneration either by increasing the total production or by decreasing the remuneration received by the other classes. The capitalist who corners wheat, and the miner who corners coal, are examples of the latter method. No such limitations exist, however, with regard to the face value of the wages paid; by Act of Parliament all wages might be increased arbitrarily twentyfold, but as a result the cost of living would rise in a similar ratio.

Incalculable harm has been done by ignorance and wilful misrepresentation. During a generation the working classes have been told, and have firmly believed, that they receive but a tithe of the value of their work, and that the bulk goes to swell the fortune of the capitalistic class. The actual facts so far as engineering is concerned will be found in the address of my predecessor in this chair. On an average in pre-war days the share of the capitalist was one-ninth that of the workman. The actual position with regard to coal is now known to all. For each ton raised 19*s.* 5½*d.* goes for labour and a total of 2*s.* is paid as royalties, owners' profits, and owners' compensation. It is obvious that the 13*s.* rise in the miner's wages cannot be paid out of profits and royalties amounting to a total of 2*s.*, but the miner, who has been brought up to believe in the fabulous profits of the wicked duke, is quite ready to strike against the owners, the Government, and the laws of arithmetic.

These facts, though clearly established, are not easily credited by the working man; he may have received a penny for what he considers is the manufacture of an article and sees it selling for a shilling in a shop. He forgets that the price must include, not only his wage, but that of the men in the mine, the smelting works, and the rolling mill, who provided the material in the shape required, the wages of the men who built the factory in which he works and made the machine he uses, the wages of transport workers, packers, shop assistants, advertising agents, printer, papermakers, etc., and that, finally, some minute fraction of a farthing might with justice be allotted to the engineer who designed the machine or invented the process. The general position, though similar, cannot, unfortunately, be followed so closely; the limitations, however, are clear. The income of the United Kingdom per head of the population was before the war about 50*l.* If, therefore, the State were run on completely communistic lines, and if under these conditions there were no reduction either in the working hours or the output our wages would average a sovereign a week each, and we could buy our goods at pre-war prices.[1]

The above considerations indicate that a real improvement in material welfare is necessarily associated with increased production. The needs of mankind are many, its desires are unlimited, and for this reason general over-production need never arise. Many circumstances may, however, lead to uneven balance, and unfortunately, when this occurs, the producers of the commodity which is in excess are penalised, and those responsible for a deficiency are rewarded. The instability is fostered and increased by speculation, and, although it forms the most powerful check on national prosperity, no serious effort has yet been made to apply a remedy.

I am inclined to think that two of the most important problems of our time relate to economic balance and increased production. The solution in the former case is dependent on the statesman, the economist, and the business man, in the latter on the combined efforts of various branches of applied science, and more especially on engineering.

At one time production was directly dependent on muscular effort; it is now mainly influenced by equipment, organisation, and skill. Increased production

[1] This statement is optimistic in so far as it does not take account of war losses.

does not necessarily imply harder work or longer hours; it can be secured by improvements in method and machinery, but only with the willing co-operation of all concerned.

Before the war the Americans were far ahead of us in standardisation and specialised machinery. The American clock and the Ford car are two well-known examples. During the war we adopted and developed these methods. As a result, although the cost of all materials increased considerably, although the wages more than doubled and the profits were more than adequate, the cost was in many cases reduced. Thus the eighteen pounder shell fell from 22*s.* to 12*s.*, the Lewis gun from 165*l.* to 62*l.* The importance of standardisation has been fully realised by the manufacturers of this country, and as a result we may hope to see a general reduction in cost.

The economic value of an individual depends exclusively on the nature, quality, and quantity of his output, and his remuneration should correspond to his economic value. The rule is simple, its application would solve most of the problems which vex the present generation, but no scheme has yet been evolved to make its application possible.

There can be no doubt that in this respect our present system is a complete failure. It has been built up casually in the course of the industrial warfare of the last twenty years, and each side, regardless of consequences, has entrenched itself in any position won. The result is a system nearly perfect from the point of view of offence and defence, well arranged for mutual destruction, but, like the trenches in France, unsuitable for use in time of peace.

The minimum wage is beneficial in so far as it prevents sweating, but in two other respects its consequences are most unfortunate. Under the operation of this rule the man whose value is a fraction below the minimum is unemployed and economically unemployable. Further, the minimum wage becomes the standard wage, and the better men are inadequately paid. Both causes lead to decreased production. The weaker or less skilful men drift into enforced idleness, and become a charge to the community under the heading of charity, poor-law, or some newly invented euphemism. The better men, finding extra effort uncompensated, drop to an ever-decreasing minimum. Small output is in most cases the result of inadequate incentive rather than active restriction. Promotion by seniority is an example of a similar cause, producing similar effects in other classes of the community.

Among the professional and business classes the remuneration is proportional to the skill and to the effort; a barrister, an engineer, or a merchant has neither minimum wage nor fixed maximum output, and, the vagaries of chance excepted, generally speaking gets what he is worth. At the two extremes stand riches and starvation, and the economic world can offer no stronger motive forces than the allurements of the one, the fear of the other. There is no absolute reason why the working man should not be offered the same incentives to hard work and progress, but up to the present most efforts have tended in the opposite direction. Any form of payment by result is viewed with indifference or distrust by the Unions, and past experience with piece work explains that attitude. There has been a disposition for employers to make large individual earnings an excuse for cutting rates. Errors in rate fixing may easily arise, and in certain cases special investigation might be necessary, but the advantages of high individual production are so great to both employer and employed that in all cases of doubt the higher rate should be maintained. In this connection the method of time-study first developed by Taylor in America and the various systems of payment by results which have been successfully applied deserve careful consideration.

Another important but difficult subject is the distinction drawn between skilled and unskilled labour. The experience gained during the war has proved that many operations scheduled as skilled work could be effectively performed by women who had only received a few weeks' special instruction. The oft-repeated demand for equal opportunity for all becomes a senseless parrot cry if it does not imply that an individual has the right to undertake better remunerated work if qualified to do so. It is a misconception which leads the skilled worker to believe that such a concession would reduce his earnings. Just as it is clear that if labourers and skilled men were grouped together at a uniform wage, that wage would necessarily be lower than the present minimum for skilled work,

so also the separation of tasks which require but a nominal period of training would increase the rate of remuneration available for the really skilled man.

I have drawn attention to some of the difficulties which must be solved if the country is to emerge from the present crisis prosperous or even solvent. There is little doubt that an elucidation is possible, but it can only be evolved by the honest and intelligent collaboration of all parties concerned, a task rendered difficult or impossible by mutual distrust and class hatred. Class differences there are, and always will be; they exist as the result of breeding, education, and environment, but they do not extend to the fundamental characteristics of humanity. Many dukes and many miners are lazy; most capitalists and most trade unionists are greedy; all men, with a few exceptions, are selfish. The war has shown that lazy, greedy, and selfish men will die or even work for their country in a great exigency, but there is a limit to and a reaction after any profound emotional stimulus, and the present unrest and dissatisfaction are but normal symptoms. A satisfactory economic system can only be based on natural human impulses, and of these the most fundamental is self-preservation, or, more generally, self-interest. Increased production is at the present moment the most pressing national need, but it will become effective only when for every man increased production becomes the talisman by which *his* paper wages can be turned to gold.

The following Report was then received :—

Report on Complex Stress Distribution.—See Reports, p. 465.

In the afternoon a Sectional Visit was paid to the Tramways Generating Station.

WEDNESDAY, SEPTEMBER 10.

The following Papers were read :—

1. *Account of the British Tanks used in the War.* *By* Sir Eustace Tennyson D'Eyncourt, *K.C.B.*[1]

The paper began with a brief account of the earlier history of tanks and inventions leading up to the idea of the use of tanks.

It then showed how, owing to the fact that the war had become one of position, it became necessary to devise some means of breaking through the enemy lines, and the idea of machines which could cross trenches and destroy machine-gun positions and other defences presented itself very strongly to many who were thinking of the tactics to be devised with this in view.

The use of armoured cars by the Royal Naval Air Service led some officers of that Service to bring the matter before the First Lord of the Admiralty, Mr. Churchill, who took up the idea and established a Landship Committee at the Admiralty to investigate the question of building landships.

The Committee carried out many experiments, some with tractors of agricultural type obtained from the United States and other devices which finally led to the War Office laying down certain requirements which had to be embodied in the design of a machine-gun destroyer.

The design was worked out concurrently with other experiments, and finally 'Mother Tank' was built to fulfil the War Office requirements, and went through its trials early in 1915.

After this further tanks were ordered, and the paper described the various types and the considerations which led up to their adoption, giving the technical details.

Mention was made of the actions in which the different tanks were used,

[1] See *Engineering*, Sept. 12, 1919, p. 334.

and reference was made to the anti-tank devices used by the enemy. Reference was also made to the tanks made by the French, and also to the few that were made by the Germans as a reply.

There was a section referring to the tactics of tanks and general considerations from a tactical and strategical point of view.

The paper concluded with a reference to the fact that the British engineers were able to introduce a new engine of war in advance of anything which the enemy had been able to devise, and that in this advance British engineers kept ahead to the end of the war, the importance of maintaining this position being emphasised.

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2. *Portable Military Bridges.* *By* Professor C. E. Inglis.[2]

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3. *Development of Geared Turbines for the Propulsion of Ships.* *By* R. J. Walker.[3]

Although the successful application of the steam turbine to marine propulsion dates back to the year 1897, when Sir Charles Parsons demonstrated in that now historical vessel, the *Turbinia*, the great advantages of the turbine system when applied to the propulsion of ships, it is only within the last few years that mechanical gearing has been largely adopted in association with steam turbines.

The author dealt with the application of the steam turbine when directly connected to the propeller shaft both in war and mercantile vessels of high and moderate speeds.

The chief governing factors in marine steam turbine design are those of economy, weight, and first cost, and it was found in actual practice that the problem of applying the turbine direct to the propeller was satisfactorily solved to fulfil these conditions for vessels of about 18-knots speed and upwards.

Up to the year 1909 the steam turbine had not been applied to vessels of slow and intermediate speeds, with the exception, in a few instances, of the combination of reciprocating engines with a low-pressure turbine.

In view of the success obtained by Dr. De Laval, of Stockholm, with helical gearing in connection with his turbine for land purposes for powers up to about 600 b.h.p., Sir Charles Parsons decided to test turbines mechanically geared to the screw shaft in a typical cargo vessel, and in 1901 experiments were carried out, the results of which fully demonstrated the suitability of mechanical gearing for the propulsion of ships.

Several forms of gearing have been proposed, such as electrical, hydraulic, and mechanical. Electrical and hydraulic transmission gears have been fitted in a few ships, but the greater majority have been fitted with mechanical gearing.

Although gearing was primarily introduced to widen the field of operation of the turbine by its adoption for vessels of low speed, it was quickly recognised that increased efficiency in fast vessels could be obtained by means of reduction gearing.

The author referred to the progress that has been made in the application of mechanical gearing for both war and merchant ships, and the advantages that have accrued by its adoption. Vessels have been put into commission with installations of geared turbines of 100,000 horse-power each, the horse-power actually transmitted through a single gear being 25,000, and the power through a single pinion reaching 15,500 shaft-horse-power.

At the present time the total number of vessels with geared turbines for war and commercial vessels built and under construction is 818, corresponding to a total shaft-horse-power of sixteen millions.

The increased efficiency that has been effected since the earlier days of the steam turbine; the measures taken to produce quiet running gears; the advance

[2] See *Engineering*, Sept. 26, 1919, p. 408.

[3] See *Engineering*, Sept. 19, 1919, p. 386.

made in the design of gears; the introduction of double reduction gears; maintenance of efficiency and economy under long continued service as the result of actual experience; and the application of geared turbines for land purposes were all dealt with by the author.

In the afternoon a Sectional Visit was paid to Christchurch R.E. Training Camp, when a demonstration of bridge-construction was given.

THURSDAY, SEPTEMBER 11.

The following Papers were read :—

1. *Airships. By* Wing-Commander T. R. Cave-Browne-Cave, *C.B.E.*[1]

The paper is intended to set out the present difficulties in development and the lines along which future research is required.

The principal difficulty experienced with the use of airships in tropical climates is the deterioration of the strength and gastightness of the fabric under the action of light. The gastightness of the bags of a rigid ship is obtained by goldbeater's skin, the supply of which is very limited, and a substitute of equal gastightness and low weight is badly wanted.

An important function of the outer cover of a rigid ship is to reflect as much as possible of the light and heat which falls upon it. This is necessary in order to reduce the superheating of the gas to a temperature above that of the surrounding air, thereby causing a false lift, which decreases as soon as the intensity of radiant heat is reduced.

The reinforcement of non-rigid envelopes is discussed. It is suggested that fabric, which is usually of equal strength in both warp and weft directions, should be reinforced by circumferential bands of string tape, which will supply the excess of the circumferential tension over the longitudinal tension.

Attention is drawn to the relative unimportance of permeability to hydrogen as compared with ability to resist the passage of air into the gas space, as air which has leaked in can only be eliminated by the discharge of large quantities of gas.

The importance of being able to take weight into the ship during flight to compensate for superheating or for petrol consumed is discussed.

Experiments have been made in using hydrogen as supplementary fuel. It is found that the use of hydrogen alone causes excessive detonation, but by suitably proportioning the mixtures of hydrogen and petrol, satisfactory running can be obtained, and very considerable economy of fuel achieved.

Attention is drawn to the much greater relative importance of fuel economy than engine weight, which obtains in an airship by reason of the much greater duration of flight. The need of accessibility and ease of repair during flight are discussed, and also various minor aspects in which the ideal airship engine differs from that of the aeroplane.

The desirability of having a propeller of variable pitch and one capable of sufficient variation to produce reverse thrust is discussed.

Attention is drawn to the necessity of obtaining some method of determining the height of an airship by means other than barometric pressure, so that the reading of the barometer at a point on the ground below the airship can be taken for meteorological purposes.

Attention is drawn to the improved ratio of weight carried to fuel expended, which results from increased size. It is shown that the limitation to the size of a rigid airship is set by the diameter of cross-section, which is possible in view of the lateral pressure of the gasbags when unequally inflated. In the case of a non-rigid ship without effective transverse bulkheads, the

[1] See *Engineering*, Sept. 12, 1919, p. 356.

limitation to size is probably set by the accumulation of pressure at the upper end of a long ship when at a considerable angle of pitch.

It is shown that a non-rigid ship of 500,000 cubic feet capacity and a rigid ship of 2,000,000 cubic feet capacity are each capable of carrying a useful weight equal to about 50 per cent. of their displacement. The relatively high ratio in the case of non-rigid ships renders it most desirable that ships of this type should be developed and considered where the loads to be carried and the distances to be covered are not so great as to render the more expensive rigid construction necessary.

Particulars are given of the recent success obtained in mooring out a rigid airship to a mast. She remained for three weeks in charge of watches, each consisting of one N.C.O. and five men, and experienced gusts up to 43 m.p.h., very heavy rain, bright sunshine, and several thunderstorms, including one of exceptional violence. This development is one of the greatest importance, as it materially reduces the difficulties of landing and handling an airship.

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2. *The Scientific Progress of Aviation during the War.* By L. Bairstow, *F.R.S.*[2]

At the beginning of the war aeroplanes had a maximum speed of 85 to 90 m.p.h., and were capable of climbing to a height of 10,000 ft. At the end the greatest speed was over 130 m.p.h., and the greatest height reached over 25,000 ft. in the fighting scouts. The weight-carrying aeroplanes used for bombing were of similar speed to those of the earlier period of the war, but the weight has increased from 2,000 lb. to nearly 30,000 lb., with a possible non-stop journey of 2,500 miles. It is not economical in fuel to fly fast, and there seems to be no possibility of producing the highest speed and the greatest load-carrying capacity in a single craft. The increase in performance has been made chiefly by increased horse-power, the aerodynamics having been well found from the beginning and subject to little change.

When dealing with control and stability as distinct from performance aerodynamic progress has been continuous and is still far from completeness. The aim in the fighting scouts has been to give the pilot power to manœuvre with least effort, whilst in the bombing aeroplanes inherent stability has been sought in order to render manual control unnecessary for the greater part of the period of flight.

Many experiments have been made, both on the model and full scales, but most of the detailed design in an aeronautical drawing office is based on model tests which in many directions are well ahead of application. The theory of the relation between tests on models and on the full scale is of considerable importance and has its special difficulties. It is not possible, as in the case of ship models, to make full use of a law of corresponding speeds, since the requirements indicated involve forces on the model equal to those on the full scale without using velocities in excess of 500 square feet. Apart from changes at the velocity of sound, which affect airscrews to a very great extent, there are critical velocities of fluid motion determined by viscosity. The existence of such a change between model and full scale would render model tests of little utility, for the connection between the flow above and below the critical velocity is frequently very slight. The criterion for change is departure from the law that resistance varies as the square of the speed, and experiments have been made in the last few years which cover all the important parts of an aeroplane. For wings the pressure at points on a section has been measured, both in flight and on a model, and the agreement is close. Model testing is now firmly established and gives confidence in attacking the complex problems of stability and control on which the safety of aeroplane transport depends.

The truth of the last observation is shown by a comparison of calculations made some years ago on the nature of disturbed motion following Bryan's mathematical theory and observations taken during flight in the last two years. All the salient features are indicated by the theory which has been extended

[2] See *Engineering*, Oct. 10, 1919, p. 493.

to cover flight in a natural wind. The importance of considering the natural motions of aircraft has an importance in the design of automatic controls which, in addition to inherent stability, may be expected as aids to comfort in flying. There is ample evidence in accident statistics to show that unstable aeroplanes are dangerous.

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3. *The Variation of Engine Power with Height.* *By* H. T. Tizard.[3]

In the early days of the war, when it was decided to reduce all officially observed 'performances' of aeroplanes to a standard atmosphere, it was assumed that the horse-power of an engine depended on the engine revolutions and the density of the atmosphere, and was independent of atmospheric temperature so long as the density remained constant. If the error involved in this assumption is large, the standard method of reducing performances becomes unreliable, and the accuracy of comparisons between model and full scale experiments in aerodynamics is considerably affected. The opposing theory that engine power depends only on the pressure, and not on the density, of the atmosphere has recently found considerable support. In this paper the accumulated evidence from actual flight tests, and from experiments on the ground under artificial altitude conditions, is examined, and it is concluded that, although the density theory is not quite true, the standard method of reducing performances is satisfactory when extreme accuracy is not desired. For accurate comparisons of full scale and model experiments special corrections must be introduced.

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4. *Sound Emission from Airscrews.* *By* Professor G. H. Bryan, *F.R.S.*

When airscrews were run on the large whirling arm of the Royal Aircraft Establishment the sound emitted showed only faint traces of the low bass note, resembling an organ tone, which is often conspicuous when aeroplanes are flying overhead; on the contrary, the principal sounds of definite pitch heard were roughly of 400, and in lesser degree 200, vibrations per second, the calculated pitch due to the revolution of the blades being about 70, 40, and 30 per second in the several cases. When, however, the screws were mounted in *fixed* bearings on the spinning tower, and the sound observed in the neighbourhood of the plane of rotation, the low bass notes were very conspicuous and agreed closely with the number of beats per second calculated from the revolution of the blades—namely, 50, 55, and 60 for a three-bladed screw and 33, 37, and 40 for a two-bladed screw at 1,000, 1,100, and 1,200 revolutions per second. With the two-bladed screw running at the higher speed the octave (say 80 per second) was also conspicuous.

In the case of an airscrew of which the tip velocity exceeded the velocity of sound (say 1,180 feet per second), an extremely unpleasant crackling sensation was experienced in the neighbourhood of the plane of rotation.

The observations lead to the conclusion that when an aeroplane is observed flying sideways the low organ-pipe tones that are observed are due to the direct action of the blades of the screw upon the air, but their intensity decreases as the angular distance of the observer from the plane of rotation increases, thus accounting for the rise and fall of the sound with the rotary oscillations of the aeroplane, as well as for the unfavourable results obtainable in the whirling arm tests. As, however, the pulsations of an eight-cylinder engine agree in frequency with those of a four-blade screw, tones of nearly the same pitch may also be produced by the engine, and these are often heard when an aeroplane is receding. They differ in tone quality from those due to the screw, and the motion of the machine gives rise to a slight difference in pitch.

In the case in which the tip velocity exceeds the velocity of sound, the disturbances produced in three different positions of the tip may reach the observer at the same instant during a certain portion of each period, and at the beginning and end of this portion the disturbance *theoretically* becomes

[3] See *Engineering*, Oct. 17, 1919, p. 527.

infinite, thus accounting for the unpleasant sensation and its limitation to a very narrow zone near the plane of rotation.

A systematic study of the phenomena involves an examination of the theoretical sound effects due to moving surfaces and moving sources, and certain difficulties present themselves which were evidently anticipated by the late Lord Rayleigh in his "Theory of Sound." So far as these difficulties are due to physical considerations I find that they in great measure disappear, when instead of working with the *velocity potential* we notice that it is on the *condensation* that the sound effects mainly depend. At this stage the mathematical work becomes rather heavy, and confirms Messrs. Lynam and Webb's use of Bessel's Functions in this connection. I have, however, given a simple graphical construction for the vibration curve due to a revolving source, with special reference to cases in which the velocity of revolution exceeds the velocity of sound. The fluctuations producing the effect of sound are due partly to the varying distance of the source from the observer, and partly to the variations in the interval between the time of emission and the time at which the disturbance reaches the observer. An important practical application consists in determining theoretically the law according to which the intensity of the sound should diminish with the distance as well as its dependence on the rate of revolution. So far as can be ascertained at present, the effect of a revolving source is more like a doublet than a variable fixed source, the condensation due to the former varying as the inverse square, and of the latter as the inverse first power, of the distance. On this assumption the sound of the exhaust should be heard further off than that of the airscrew, even when both are of the same pitch.

For arranging the Farnborough experiments thanks are due to Mr. McKinnon Wood and Mr. Lynam.

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5. *The Problem of Steep Landing and Short Run by Wind Tunnel Investigation.* *By* R. Rolleston West, *D.S.O., B.A., A.M.I.C.E.*

With the advance of commercial aviation, the problem of landing in a small area over obstacles is assuming great importance, both from considerations of safety and expense. The two essentials to its solution are steep gliding angle and slow landing speed. Till now these two desiderata have been mutually contradictory.

Mechanical landbrakes are inadequate, as an aeroplane when landing is largely supported still on the wings. There remains aerodynamic methods.

With the engine cut off, two air forces act on the machine, the Lift L and Drag D. The ratio L/D measures both gliding angle and efficiency, hence, unfortunately, the more efficiency the flatter the gliding angle and the larger the aerodrome required.

The three aerodynamic requirements for landing in a small aerodrome are a large drag coefficient K_x, a large lift coefficient K_y, and a small K_y/K_x ratio. The second is important, since landing speed V varies as $\frac{1}{\sqrt{K_y}}$ and energy of machine to be dissipated varies as V^2.

A wing flown near its stalling angle complies with these three requirements, but insufficiently.

Experiments carried out in the wing tunnel of the Aircraft Manufacturing Co., Hendon, showed that flaps along the wing greatly increased drag, but reduced lift; hence landing speed was high and lateral control was also impossible.

A normal plane between wings also spoilt lift, and filling in undercarriage struts gave inadequate drag.

Experiments on a special aerofoil showed that dipping the trailing edge gave high lift, but not very large drag; while dipping leading edge gave very high drag and a slight reduction in lift. In the case of dipping the trailing edge, the aeroplane would have to fly very much nose down so as not to stall. In the case of the dipping leading edge the opposite effect is obtained and the attitude

would be nearly normal, though the whole machine would be coming down at a steep angle. This latter would be an advantage in the hands of an inexperienced pilot in that he would be less likely to stall the machine in flattening out.

The data obtained may be summarised by the following comparative figures, taken from a large table of results compiled :—

Model	K_y max.	L/D	Distance flown from 50 feet	Distance run	Total distance to stop
R.A.F. 15, dippg. leadg. edge 45°	·477	1·86	93	261	354
R.A.F. 9, ,, trailing ,, 60°	·840	3·30	165	197	362
R.A.F. 15, normal plane	·505	8·71	436	490	926
,, flap on leading edge...	·445	2·32	116	312	428
D.H. 4, airbrake on undercarriage	·500	5·68	284	413	697

The aeroplane is assumed to come in at a height of 50 feet in each case.
Distance run is calculated from equation

$$S = \frac{62{\cdot}5 \log_e K_x - \log_e K_y}{K_x - \mu K_y},$$

μ being a friction factor.

From the above it is seen that airbrakes alone are not of much effect. Varying camber, however, seems likely to afford a better solution of the problem.

In the afternoon a Sectional Visit was paid to the Bournemouth Gas and Water Company's Works.

FRIDAY, SEPTEMBER 12.

The following Papers were read :—

1. *Wireless Navigation for Aircraft.* *By* Captain J. Robinson, *R.A.F.*

Navigation for aircraft differs from that at sea because of the great importance of drift. This prevents dead reckoning methods from being reliable. In fogs and at night it is thus desirable to be able to fix one's position, and the use of wireless bearings is the most hopeful method of progress. There are two distinct methods of employing wireless bearings in order to determine position :

(*a*) By the first method the machine transmits, and the direction-finding stations are on the ground. Each direction-finding station finds the bearing on the moving object and communicates its bearing to a central station. There the position of the moving object is worked out from the various bearings and retransmitted to it.

(*b*) By the second method the moving object, either aircraft or ship, has its own direction-finding apparatus, and finds bearings on fixed transmitting stations.

Method (*a*) has considerable draw-backs ; the first being that in case of war when the aircraft transmits to ask for its position this is also disclosed to the enemy.

Secondly, only very few aircraft can be dealt with, as a considerable amount of transmission is required for a single aircraft to find its position. In consequence, it was decided to attempt to use method (*b*) in the British Air Service.

Most of the methods known at the beginning of the war for determining bearings were minimum methods ; that is, for accuracy, it was necessary to find

where the signal vanished. In consequence of the large disturbing noises on aircraft, this minimum method was not considered to be accurate enough. It is necessary to use a system where signals can be heard whilst the bearing is taken. The system devised is to use two coils at right angles, which can be rotated together on a vertical axis. One coil alone is used first, and the system rotated to be somewhere near the maximum of this single coil. Then the second coil is introduced and its effects added to or substracted from those of the first coil. If the first coil is correctly on its maximum, then the second coil will be on its minimum, and thus there is no change of intensity on adding or substracting the effects of this coil by a reversing switch.

This system was applied to aeroplanes in two ways :

(*a*) *The Wing Coil System.*—In this case the aerials are fixed rigidly to the aeroplane which have to be rotated in order to determine bearings. This system is particularly useful in flying towards an objective where there is a wireless station.

(*b*) *Rotating Coil System.*—In this case rotating coils were placed in the fuselage and rotated independently of the machine. Considerable difficulties had to be overcome to bring the R.A.F. system to a stage of perfection :

(*a*) The external noises on an aeroplane.

(*b*) The disturbances due to the magneto which produce considerable noise in the telephones. The cause of this disturbance was traced to the emission of very short waves by the magneto, the wave length being of the order of from 5 to 30 metres.

(*c*) When using the fuselage coil system it was found that corrections had to be applied for the deviation produced by the metal work of the aircraft.

In addition to the preceding difficulties there is another trouble in the variation of bearings produced by atmospheric influence. The extent of these variations is not large, possibly never more than about 3 deg. when using waves of 2,000 metres and upwards.

In spite of the preceding difficulties excellent results have already been obtained. A large number of flights have been made, and it has been found that the mean error of bearing is $1\frac{3}{4}$ deg. when using beacon stations whose distance varies from 20 to 500 miles.

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2. *The Three-electrode Thermionic Valve as an Alternating Current Generator.* *By* Professor C. L. Fortescue.[1]

1. The paper refers mainly to the theory of the valve and circuits as worked out in the course of the development of Naval Wireless Telegraphy. This development was relatively slow at first, but after the success of the first valve transmitting sets fitted in 1917 became very much more rapid.

2. The action of the valve and circuit in generating an alternating current is first explained by the aid of a mechanical analogy. An arrangement of a spring-controlled piston, a system of water connections, and a double-ported water valve can be imagined which has properties closely analogous to the capacity-inductance circuit used with the thermionic valve.

3. An approximate theory of the conditions that have to be satisfied is worked out on a power basis. The necessary conditions for the maximum power output from the tube are explained by means of the contour characteristics.

4. The paper is concluded by a short description of certain of the valve transmitting sets actually in use in the Naval Service.

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3. *A Method of using Two Triode Valves in Parallel for Generating Oscillations.* *By* Professor W. H. Eccles *and* F. W. Jordan.[2]

The method described consists in arranging two triode tubes so that they act in turn symmetrically upon an inductance-capacity circuit, one of the tubes

[1] See *The Electrician*, Sept. 19, 1919, p. 294 ; *Engineering*, Oct. 10, 1919, p. 491.

[2] See *The Electrician*, Sept. 19, 1919, p. 292 ; *Radio Review*, Vol. i., p. 80.

strengthening the positive phase of the oscillations, the other the negative phase. This is accomplished by causing the oscillations in the inductance-

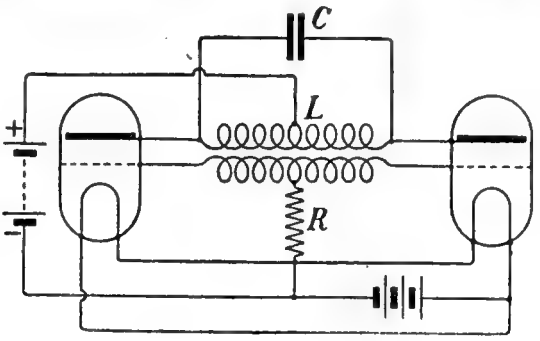

FIG. 1.

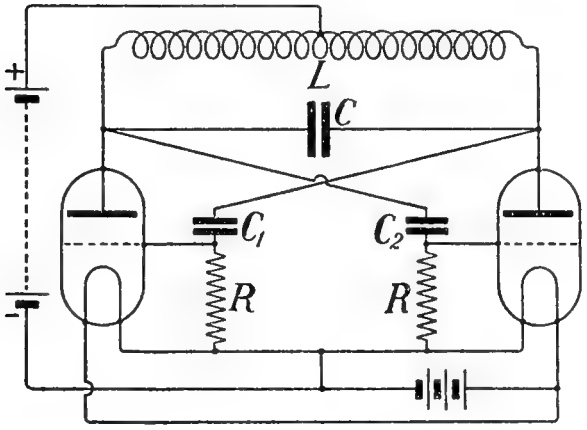

FIG. 2.

capacity circuit to act upon the two grids in opposite senses. Of many possible circuits the two shown in the accompanying figures have proved very convenient.

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4. *A Trigger Relay utilising Three Electrode Thermionic Vacuum Tubes.* *By* Professor W. H. ECCLES *and* F. W. JORDAN.[3]

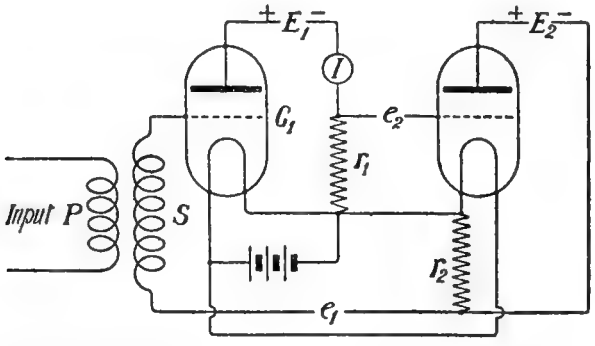

FIG. 3.

[3] See *The Electrician*, Sept. 19, 1919, p. 298; *Radio Review*, Vol. i., p. 143.

This is a form of cascade amplifier with resistance coupling. An even number of valves must be employed, and back coupling from the last to the first produces the required trigger action. One of the forms described is seen in figure 1. When the grid G_1 becomes positive, say, on account of the arrival of an electric stimulus, the anode current through r_1 becomes greater, and the potential of the second grid falls. In consequence the anode current through r_2 decreases, and therefore the potential of G_1, to which r_1 is connected, becomes more positive. As there is no restoring influence, the anode current through the instrument I increases to the highest capacity of the tube and battery.

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5. *Gaseous Ignition by Hot Wires.* *By* Professor W. M. Thornton, *D.Sc., D.Eng.*[4]

This question is important where the possibility exists of inflammable gases coming into contact with incandescent wires, in coal mines or submarines, for example. From an examination of the behaviour of wires of platinum, nickel, iron, tungsten, molybdenum, gold, and silver heated by electric current in mixtures with air of hydrogen, methane, ethane, pentane, ethylene, methyl and ethyl alcohol, ethyl ether, benzene, coal gas and petrol, the following conclusions were reached :

1. The least igniting current is a linear function of the diameter of the wire.
2. Ignition is for a given size of wire independent of the calorific value of the gas.
3. It is independent of gas pressure down to a limit of about 10 cm. Hg, when it suddenly fails. Above atmospheric pressure it rises slightly. A platinum wire ·02 cm. diameter ignites hydrogen (30 per cent.) at 5·45 ampères at atmospheric pressure, and at 6·0 ampères at 100 lb. per sq. inch.
4. Gaseous combination, which proceeds automatically to explosion, begins, in the case of platinum wires, with the wire at about 200 deg. C., well below red heat.
5. With an explosion vessel of 50 c.c. volume it is practically impossible to ignite methane by hot wires. Platinum wires glow white-hot and melt, but do not ignite the gas, which, on being tested afterwards with a spark discharge, immediately explodes.
6. Electric and magnetic fields have no direct influence on hot-wire ignition.
7. The temperature of platinum wires glowing brightly by surface combustion is, when measured by its change of electrical resistance, much lower than the apparent optical temperature.
8. Ignition is traced to an action occurring, if not within the surface layer of the metal itself, so close to it that the ordinary gas laws do not come into action. It is inferred that the mechanism of hot-wire ignition is an attack upon oxygen either within the wire or by positive ions of combustible gas ejected from it.

In the afternoon a Sectional Visit was paid to the Royal Naval Cordite Factory, Halton Heath.

SATURDAY, SEPTEMBER 13.

The following Papers were read :—

1. *Submarine Mining.* *By* Commander A. L. Gwynne.[1]

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[4] See *Phil. Mag.*, 38, p. 613, 1919.
[1] See *Engineering*, Sept. 19, 1919, p. 389.

2. *The Paravane.* *By* Robt. F. McKay, *M.Sc., A.M.Inst. C.E., A.M.I.Mech.E.*[2]

The Paravane has been developed as a weapon to fulfil two purposes :—

(1) To attack a submarine.
(2) To protect vessels from moored mines.

In order to differentiate between the two, the one used for attacking submarines is termed the 'Explosive Paravane,' and the other for protecting vessels against mines is called the 'Protector Paravane.' A further differentiation in Protector Paravanes has been to call all those used for protecting warships 'Protector Paravanes,' and those used for protecting merchant vessels 'Otters.'

The basic principle of all three is the same. They are in effect a form of water-kite which can be towed by a vessel and will run outwards and downwards from the towing vessel.

The Explosive Paravanes carry a large charge, amounting in some cases to over 300 lb. of T.N.T. The Protector Paravanes, or Otters, carry a form of cutter, but no explosive charge whatever, the cutter being used for severing the moorings of the mines.

In general, a vessel fitted with either form of apparatus tows two Paravanes, one on either side, by specially manufactured wires. A depth-keeping mechanism is fitted in the tail of the Paravane or Otter whereby the depth at which it is being towed may be previously fixed. Variations in the speed or course of the vessel thus have no effect upon the depth of the Paravane.

Explosive Paravanes are necessarily more complex than the protector type, and, in addition to their charge of T.N.T., carry the necessary firing gear and depth-recording device, etc. The explosive charge can be detonated by an electric current which passes through a core in the towing wire. Various methods of detonation, automatic or deliberate, are arranged. Safety devices are inserted in the firing circuit so that the Paravane cannot be accidentally fired whilst it is on deck or in the water near the ship.

The method of attack by the Explosive Paravane against a hostile submarine is for the attacking vessel to proceed to the spot where the submarine was last seen, and there to rake the water with the two Paravanes, which will be towed at a depth of perhaps 200 feet.

The success of the Explosive Paravane has been very remarkable, when it is realised that this form of attack is only used when other methods, such as the torpedo, the gun, or the ram, have failed. The only form of attack of a like nature is the depth charge. In comparing the results obtained by the Paravane with those obtained by the depth charge, statistics show that the depth charge destroyed four times as many submarines as the Paravane. Due consideration must be given, however, to the fact that depth charges were fitted in twenty-five times as many vessels, and accordingly, proportionately to the number of vessels fitted, the Paravane is many times more efficient.

The action of a Protective Paravane or Otter can best be likened to a broad wedge being formed in the front of the towing vessel. Each Paravane is towed from a point as far forward and as low down as possible by a specially constructed steel wire, and the hydroplane on the Paravane exerts a heavy pull upon these wires. These wires, therefore, form a wedge, kept in place by the tension produced by the dynamic reaction of the water upon the Paravane. Mine-mooring wires which strike this wedge are deflected away from the ship, and passing along the towing wire are guided into the cutter jaws on the head of the Paravane and instantaneously severed. The mine-sinker drops to the bottom of the sea, whilst the mine floats to the surface, where it can be seen and destroyed by gunfire.

The success of the Protector Paravane or Otter has been even more striking than that of the explosive type. Out of just under 200 British war vessels fitted with this device, fifty-three have cut mines involving a total tonnage of over half a million tons, and representing a money value of about sixty millions sterling.

[1] See *Engineering*, Sept. 19, 1919, p. 389.

Of British merchant vessels, 2,700 have been fitted, but, owing to less accurate reports being obtained from merchant vessels as compared with warships, the actual results are not known. If, in comparison with British warships, only one-tenth as many merchant vessels, as compared to the number fitted, have been saved, the saving to the country in tonnage has probably been much in excess of one hundred million sterling.

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3. *The Thermal Conductivity of Solid Insulators.* *By* Professor W. M. Thornton, *D.Sc.*, *D.Eng.*[3]

Thermal conductivity of metals has been adequately explained by the electron theory of matter. In the case of insulators the argument does not hold, and the mode of conduction in substances such as quartz or wax has not been worked out. There is a simple relation between the coefficient of thermal conductivity k, the density ρ, and the velocity of sound V, in a solid which throws much light on the process. It is that $k = V^2\rho^3$, and since $V^2 = E/\rho$, where E is the elasticity, $k = E\rho$. These relations hold for all true solid insulators, but not for indiarubber or cork which have peculiar elastic properties. For example:

Material.	Density.	Elasticity.	Velocity of sound.	$E\rho$.	$V^2\rho^2$.	k
Flint glass ...	2·9	$4{\cdot}8.10^{11}$	$4{\cdot}1.10^5$	14·1	14·1	14·3
Graphite ...	2·3	5·25	4·65	12·1	11·5	12·0
Paraffin wax ...	0·91	0·154	0·13	0·14	0·14	0·141

From the kinetic energy of vibration $\frac{1}{2}mv^2$ it is found that the ratio of the velocity of sound to the velocity of atomic vibration by which heat is transmitted in insulators is $2{\cdot}9.10^{10}$. It is shown that the coincidence of this with v can be explained and a reason given for the rule $k = V^2\rho^2$ by simple electromagnetic considerations. The rule is a useful test for a heat insulator; the chief qualification is that it should be light and inelastic.

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4. *The Application of Aerofoil Theory to the Heating of Buildings.* *By* Professor G. H. Bryan, *F.R.S.*

The author showed some experiments illustrating by means of smoke the deflection into the room of the upward current of heated air from a radiator placed below a window by means of an inclined plate, the layer of cold air in contact with the window remaining relatively stationary.

In the afternoon a Sectional Visit was paid to the Winton Aerodrome of the Bournemouth Aviation Company.

[3] See *Phil. Mag.*, 38, p. 705, 1919.

SECTION H.—ANTHROPOLOGY.

PRESIDENT OF THE SECTION: PROFESSOR A. KEITH, *M.D., LL.D., F.R.S., F.R.C.S.*

TUESDAY, SEPTEMBER 9.

The President delivered the following Address:—

The Differentiation of Mankind into Racial Types.

FOR a brief half-hour I am to try and engage your attention on a matter which has excited the interest of thoughtful minds from ancient times—the problem of how mankind has been demarcated into types so diverse as the Negro, the Mongol, and the Caucasian or European. For many a day the Mosaic explanation—the tower of Babel theory—was regarded as a sufficient solution of this difficult problem. In these times most of us have adopted an explanation which differs in many respects from that put forward in the book of Genesis; Noah disappears from our theory and is replaced in the dim distance of time by a 'common ancestral stock.' Our story now commences, not at the close of a historical flood, but at the end of a geological epoch so distant from us that we cannot compute its date with any degree of accuracy. Shem, Ham, and Japheth, the reputed ancestors of the three great racial stocks of modern times—the white, black, and yellow distinctive types of mankind—have also disappeared from our speculations; we no longer look out on the world and believe that the patterns which stud the variegated carpet of humanity were all woven at the same time; some of the patterns, we believe, are of ancient date and have retained many of the features which marked the 'common ancestral' design; others are of more recent date, having the ancient pattern altered in many of its details. We have called in, as Darwin had taught us, the whole machinery of evolution—struggle for existence, survival of the fittest, spontaneous origin of structural variations, the inheritance of such variations—as the loom by which Nature fashions her biological patterns. We have replaced the creative finger by the evolutionary machine, but no one is more conscious of the limitations of that machine than the student of human races. We are all familiar with the features of that racial human type which clusters round the heart of Africa; we recognise the Negro at a glance by his black, shining, hairless skin, his crisp hair, his flattened nose, his widely opened dark eyes, his heavily moulded lips, his gleaming teeth and strong jaws. He has a carriage and proportion of body of his own; he has his peculiar quality of voice and action of brain. He is, even to the unpractised eye, clearly different to the Mongolian native of North-Eastern Asia; the skin, the hair, the eyes, the quality of brain and voice, the carriage of body and proportion of limb to body pick out the Mongol as a sharply differentiated human type. Different to either of these is the native of Central Europe—the Aryan or Caucasian type of man; we know him by the paleness of his skin and by his facial features—particularly his narrow, prominent nose and thin lips. We are so accustomed to the prominence of the Caucasian nose that only a Mongol or Negro can appreciate its singularity in our aryanised world. When we ask how these three types—the European, Chinaman, and Negro—came by their distinctive features, we find that our evolutionary machine is defective; the processes of natural and of sexual selection will preserve and exaggerate traits of body and of mind, but they

cannot produce that complex of features which marks off one racial type from another. Nature has at her command some secret mechanism by which she works out her new patterns in the bodies of man and beast—a mechanism of which we were almost ignorant in Darwin's day, but which we are now beginning to perceive and dimly understand. It is the bearing of this creative or morphogenetic mechanism on the evolution of the modern races of mankind which I propose to make the subject of my address.

Hid away in various parts of the human frame is a series of more or less obscure bodies or glands, five in number, which, in recent times, we have come to recognise as parts of the machinery which regulate the growth of the body. They form merely a fraction of the body—not more than 1/180th part of it; a man might pack the entire series in his watch-pocket. The modern medical student is familiar with each one of them—the pituitary body, about the size of a ripe cherry, attached to the base of the brain and cradled in the floor of the skull; the pineal gland, also situated in the brain, and in point of size but little larger than a wheat-grain; the thyroid in the neck, set astride the windpipe, forms a more bulky mass; the two suprarenal bodies situated in the belly, capping the kidneys, and the interstitial glands embedded within the substance of the testicle and ovary, complete the list. The modern physician is also familiar with the fact that the growth of the body may be retarded, accelerated, or completely altered if one or more of these glands becomes the seat of injury or of a functional disorder. It is thirty-three years now since first one woman and then another came to Dr. Pierre Marie in Paris seeking relief from a persistent headache, and mentioning incidentally that their faces, bodies, hands, and feet had altered so much in recent years that their best-known friends failed to recognise them. That incident marked the commencement of our knowledge of the pituitary gland as an intrinsic part of the machinery which regulates the shaping of our bodies and features. Dr. Marie named the condition acromegaly. Since then hundreds of men and women showing symptoms similar to those of Dr. Marie's patients have been seen and diagnosed, and in every instance where the acromegalic changes were typical and marked there has been found a definite enlargement or tumour of the pituitary body. The practised eye recognises the full-blown condition of acromegaly at a glance, so characteristic are the features of the sufferers. Nay, as we walk along the streets we can note slight degrees of it—degrees which fall far short of the border-line of disease; we note that it may give characteristic traits to a whole family—a family marked by what may be named an acromegalic taint. The pituitary gland is also concerned in another disturbance of growth—giantism. In every case where a young lad has shot up, during his late 'teens,' into a lanky man of seven feet or more—has become a giant—it has been found that his pituitary gland was the site of a disordered enlargement. The pituitary is part of the mechanism which regulates our stature, and stature is a racial characteristic. The giant is usually acromegalic as well as tall, but the two conditions need not be combined; a young lad may undergo the bodily changes which characterise acromegaly and yet not become abnormally tall, or he may become—although this is rarely the case—a giant in stature and yet may not assume acromegalic features. There is a third condition of disordered growth in which the pituitary is concerned—one in which the length of the limbs is disproportionably increased—in which the sexual system and all the secondary sexual characters of body and mind either fail to develop or disappear—where fat tends to be deposited on the body, particularly over the buttocks and thighs—where, in brief, a eunuchoid condition of body develops. In all of these three conditions we seem to be dealing with a disordered and exaggerated action of the pituitary gland; there must be conditions of an opposite kind where the functions of the pituitary are disordered and reduced. A number of cases of dwarfism have been recorded where boys or girls retained their boyhood or girlhood throughout life, apparently because their pituitary gland had been invaded and partly destroyed by tumours. We shall see that dwarfism may result also from a failure of the thyroid gland. On the evidence at our disposal, evidence which is being rapidly augmented, we are justified in regarding the pituitary gland as one of the principal pinions in the machinery which regulates the growth of the human body and is directly concerned in determining stature, cast of features, texture of skin, and character of hair—all of

them marks of race. When we compare the three chief racial types of humanity—the Negro, the Mongol, and the Caucasian or European—we can recognise in the last named a greater predominance of the pituitary than in the other two. The sharp and pronounced nasalisation of the face, the tendency to strong eyebrow ridges, the prominent chin, the tendency to bulk of body and height of stature in the majority of Europeans, is best explained, so far as the present state of our knowledge goes, in terms of pituitary function.

There is no question that our interest in the mechanism of growth has been quickened in recent years by observations and discoveries made by physicians on men and women who suffered from pituitary disorders, but that a small part of the body could influence and regulate the growth and characterisation of the whole was known in ancient times. For many centuries it has been common knowledge that the removal of the genital glands alters the external form and internal nature of man and beast. The sooner the operation is performed after birth the more certain are its effects. Were a naturalist from a unisexual world to visit this earth of ours it would be difficult to convince him that a brother and a sister were of the same species, or that the wrinkled, sallow-visaged eunuch with his beardless face, his long tapering limbs, his hesitating carriage, his carping outlook and corpulent body, was brother to the thick-set, robust, pugilistic man with the bearded face. The discovery that the testicle and ovary contain, scattered throughout their substance, a small glandular element which has nothing to do with their main function—the production of genital cells—was made seventy years ago, but the evidence which leads us to believe that this scattered element—the interstitial gland—is directly concerned in the mechanism of growth is of quite recent date. All those changes which we may observe in the girl or boy at puberty—the phase of growth which brings into full prominence their racial characteristics—depend on the action of the interstitial glands. If they are removed or remain in abeyance the maturation of the body is both prolonged and altered. In seeking for the mechanism which shapes mankind into races we must take the interstitial gland into our reckoning. I am of opinion that the sexual differentiation—the robust manifestations of the male characters—is more emphatic in the Caucasian than in either the Mongol or Negro racial types. In both Mongol and Negro, in their most representative form, we find a beardless face and almost hairless body, and in certain Negro types, especially in Nilotic tribes, with their long, stork-like legs, we seem to have a manifestation of abeyance in the action of the interstitial glands. At the close of sexual life we often see the features of a woman assume a coarser and more masculine appearance.

Associated with the interstitial glands, at least in point of development, are the suprarenal bodies or glands. Our knowledge that these two comparatively small structures, no larger than the segments into which a moderately sized orange can be separated, are connected with pigmentation of the skin dates back to 1894, when Dr. Thomas Addison, a physician to Guy's Hospital, London, observed that gradual destruction of these bodies by disease led to a darkening or pigmentation of the patient's skin, besides giving rise to other more severe changes and symptoms. Now it is 150 years since John Hunter came to the conclusion, on the evidence then at his disposal, that the original colour of man's skin was black, and all the knowledge that we have gathered since his time supports the inference he drew. From the fact that pigment begins to collect in and thus darken the skin when the suprarenal bodies become the seat of a destructive disease we infer that they have to do with the clearing away of pigment, and that we Europeans owe the fairness of our skins to some particular virtue resident in the suprarenal bodies. That their function is complex and multiple, the researches of Sharpey-Schafer, of T. R. Elliott, and of W. B. Cannon have made very evident. Fifteen years ago Bulloch and Sequeira established the fact that when a suprarenal body becomes the site of a peculiar form of malignant overgrowth in childhood, the body of the boy or girl undergoes certain extraordinary growth changes. The sexual organs become rapidly mature, and through the framework of childhood burst all the features of sexual maturity—the full chest, muscularity of limbs, bass voice, bearded face and hairy body—a miniature Hercules—a miracle of transformation in body and brain. Corresponding changes occur in young girls—almost infants in years—with a tendency to assume features which characterise the male.

Professor Glynn [1] has recently collected such cases and systematised our knowledge of these strange derangements of growth. There can be no doubt that the suprarenal bodies constitute an important part of the mechanism which regulates the development and growth of the human body and helps in determining the racial characters of mankind. We know that certain races come more quickly to sexual maturity than others, and that races vary in development of hair and of pigment, and it is therefore reasonable to expect a satisfactory explanation of these characters when we have come by a more complete knowledge of the suprarenal mechanism.

During the last few years the totally unexpected discovery has been sprung upon us that disease of the minute pineal gland of the brain may give rise to a train of symptoms very similar to those which follow tumour formation of the cortex of the suprarenal bodies. In some instances the sudden sexual prematurity which occurs in childhood is apparently the immediate result of a tumour-like affection of the pineal gland. We have hitherto regarded the pineal gland, little bigger than a wheat-grain and buried deeply in the brain, as a mere useless vestige of a median or parietal eye, derived from some distant human ancestor in whom that eye was functional, but on the clinical and experimental evidence now rapidly accumulating we must assign to it a place in the machinery which controls the growth of the body.

We come now to deal with the thyroid gland, which, from an anthropological point of view, must be regarded as the most important of all the organs or glands of internal secretion. Here, too, in connection with the thyroid gland, which is situated in the front of the neck, where it is so apt to become enlarged and prominent in women—I must call attention to a generalisation which I slurred over, when speaking of the pituitary and suprarenal glands. Each of these glands throws into the circulating blood two sets of substances—one set to act immediately in tuning the parts of the body which are not under the influence of the will, to the work they have to do when the body is at rest and when it is making an effort; another set of substances—which Prof. Gley has named morphogenetic—has not an immediate but a remote effect; they regulate the development and co-ordinate the growth of the various parts of the body. Now, so far as the immediate function of the thyroid is concerned, our present knowledge points to the gland as the manufactory of a substance which, when circulating in the body, regulates the rate of combustion of the tissues; when we make a muscular effort, or when our bodies are exposed to cold, or when we become the subjects of infection, the thyroid is called upon to assist in mobilising all available tissue-fuel. If we consider only its immediate function it is clear that the thyroid is connected with the selection and survival of human races. When, however, we consider its remote or morphogenetic effects on growth its importance as a factor in shaping the characteristics of human races becomes even more evident. In districts where the thyroid is liable to that form of disease known as goitre it has been known for many a year that children who were affected became cretins—dwarf idiots with a very characteristic appearance of face and body.[2] Disease of the thyroid stunts and alters the growth of the body so that the subjects of this disorder might well be classed as a separate species of humanity. If the thyroid becomes diseased and defective after growth of the body is completed then certain changes, first observed by Sir William Gull in 1873, are set up and give rise to the disordered state of the body known as myxœdema. 'In this state,' says Sir Malcolm Morris,[3] 'the skin is cold, dry and rough, seldom or never perspires, and may take on a *yellowish* tint; there is a bright red flush in the malar region. The skin as a whole looks transparent; the hair of the scalp becomes scanty; the pubic and axillary hair, with the eyelashes and eyebrows, often falls out; in many cases the teeth are brittle and carious. All these appearances disappear under the administration of thyroid extract.' We have here conclusive evidence that the thyroid acts directly on the skin and hair, just the structures we employ in the classification of human races. The influence of

[1] *Quart. Journ. of Med.*, 1912, vol. v., p. 157.

[2] The story of the discovery of the action of the thyroid gland is told by Prof. G. M. Murray, *Brit. Med. Journ.*, 1913, II., p. 163.

[3] *Brit. Med. Journ.*, 1913, I., p. 1038.

the thyroid on the development of the other systems of the body, particularly on the growth of the skull and skeleton, is equally profound. This is particularly the case as regards the base of the skull and the nose. The arrest of growth falls mainly on the basal part of the skull, with the result that the root of the nose appears to be flattened and drawn backwards between the eyes, the upper forehead appears projecting or bulging, the face appears flattened, and the bony scaffolding of the nose, particularly when compared to the prominence of the jaws, is greatly reduced. Now, these facial features which I have enumerated give the Mongolian face its characteristic aspect, and, to a lesser degree, they are also to be traced in the features of the Negro. Indeed, in one aberrant branch of the Negro race—the Bushman of South Africa—the thyroid facies is even more emphatically brought out than in the most typical Mongol. You will observe that, in my opinion, the thyroid—or a reduction or alteration in the activity of the thyroid—has been a factor in determining some of the racial characteristics of the Mongol and the Negro races. I know of a telling piece of evidence which supports this thesis. Some years ago there died in the East End of London a Chinese giant—the subject, we must suppose, of an excessive action of the pituitary gland—the gland which I regard as playing a predominant part in shaping the face and bodily form of the European. The skeleton of this giant was prepared and placed in the Museum of the London Hospital Medical College by Col. T. H. Openshaw, and any one inspecting that skeleton can see that, although certain Chinese features are still recognisable, the nasal region and the supra-orbital ridges of the face have assumed the more prominent European type.

There are two peculiar and very definite forms of dwarfism with which most people are familiar, both of which must be regarded as due to a defect in the growth regulating mechanism of the thyroid. Now, one of these forms of dwarfism is known to medical men as Achondroplasia, because the growth of cartilage is particularly affected, but in familiar language we may speak of the sufferers from this disorder of growth as being of the 'bulldog breed' or of the 'dachshund breed.' In the dachshund the limbs are greatly shortened and gnarled, but the nose or snout suffers no reduction, while in the bulldog the nose and nasal part of the face are greatly reduced and withdrawn, showing an exaggerated degree of Mongolism. Among achondroplastic human dwarfs both breeds occur, but the 'bulldog' form is much more common than the 'dachshund' type. The shortening of limbs with retraction of the nasal region of the face—pug-face or prosopia we may call the condition—has a very direct interest for anthropologists, seeing that short limbs and a long trunk are well-recognised racial characteristics of the Mongol. In the second kind of dwarfism, which we have reason to regard as due to a functional defect of the thyroid, the Mongolian traits are so apparent that the sufferers from this disorder are known to medical men as 'Mongolian idiots'—for not only is their growth stunted, but their brains also act in a peculiar and aberrant manner. Dr. Langdon Down, who gave the subjects of this peculiar disorder the name 'Mongolian idiots' fifty-five years ago, knew nothing of the modern doctrine of internal secretions, but that doctrine has been applied in recent years by Dr. F. G. Crookshank [4] to explain the features and condition of Mongoloid imbecile children. Some years ago [5] I brought forward evidence to show that we could best explain the various forms of anthropoid apes by applying the modern doctrine of a growth-controlling glandular mechanism. In the gorilla we see the effects of a predominance of the pituitary elements; in the orang, of the thyroid. The late Professor Klaatsch tried to account for the superficial resemblances between the Malay and the orang by postulating a genetic relationship between them; for a similar reason he derived the Negro type from a gorilline ancestry. Occasionally we see a man or woman of supposedly pure European ancestry displaying definite Mongoloid traits in their features. We have been in the habit of accounting for such manifestations by the theory, at one time very popular, that a Mongoloid race had at one time spread over Europe, and that Mongoloid traits were atavistic recurrences. An examination of the human remains of ancient Europe yields no evidence in support of a Turanian or Mongol invasion of Europe.

[4] The *Universal Medical Record*, 1913, vol. iii., p. 12.
[5] *Journ. of Anat. and Physiol.*, 1913.

All of these manifestations to which I have been calling your attention—the sporadic manifestation of Mongoloid characters in diseased children and in healthy adult Europeans, the generic characters which separate one kind of ape from another, the bodily and mental features which mark the various races of mankind—are best explained by the theory I am supporting—namely, that the conformation of man and ape and of every vertebrate animal is determined by a common growth-controlling mechanism which is resident in a system of small but complex glandular organs. We must now look somewhat more closely into the manner in which this growth-regulating mechanism actually works. That we can do best by taking a glimpse of a research carried out by Bayliss and Starling in the opening years of the present century. They were seeking to explain why it was that the pancreas poured out its digestive juice as soon as the contents of the stomach commenced to pass into the first part of the duodenum. It was then known that if acid was applied to the lining epithelial membrane of the duodenum, the pancreas commenced to work; it was known also that the message which set the pancreas into operation was not conveyed from the duodenum to the pancreas by nerves, for when they were cut the mechanism was still effective. Bayliss and Starling solved the puzzle by making an emulsion from the acid-soaked lining epithelium of the duodenum and injecting the extract of that emulsion into the circulating blood. The result was that the pancreas was immediately thrown into activity. The particular substance which was thus set circulating in the blood and acted on the pancreas and on the pancreas alone, and which thus served as a messenger or hormone, they named secretin. They not only cleared up the mechanism of pancreatic secretion, but at the same time made a discovery of much greater importance. They had discovered a new method whereby one part of the human body could communicate with and control another. Up to that time we had been like an outlandish visitor to a strange city, who believed that the visible telegraph or telephone wires were the only means of communication between its inhabitants. We believed that it was only by nerve fibres that intercommunication was established in the animal body. Bayliss and Starling showed that there was a postal system. Missives posted in the general circulation were duly delivered at their destinations. The manner in which they reached the right address is of particular importance for us; we must suppose that the missive or hormone circulating in the blood and the recipient for which they are intended have a special attraction or affinity for each other—one due to their physical constitution—and hence they and only they come together as the blood circulates round the body. Secretin is a hormone which effects its errand rapidly and immediately, whereas the growth or morphogenetic hormones, thrown into the circulation by the pituitary, pineal, thyroid, suprarenal, and genital glands, act slowly and remotely. But both are alike in this: the result depends not only on the nature of the hormone or missive, but also on the state of the local recipient. The local recipient may be specially greedy, as it were, and seize more than a fair share of the manna in circulation, or it may have 'sticky fingers' and seize what is not really intended for local consumption. We can see that local growth—the development of a particular trait or feature—is dependent not only on the hormones supplied to that part, but also on the condition of the receptive mechanism of the part. Hence we can understand a local derangement of growth—an acromegaly or giantism confined to a finger or to the eyebrow ridges, to the nose, to one side of the face, and such local manifestations are not uncommon. It is by a variation in the sensitiveness of the local recipient that we have an explanation of the endless variety to be found in the relative development of racial and individual features.

Some ten years after Starling had formulated the theory of hormones. Professor W. B. Cannon, of Harvard University, piecing together the results of researches by Dr. T. R. Elliott and by himself, on the action of the suprarenal glands, brought to light a very wonderful hormone mechanism—one which helps us in interpreting the action of growth-regulating hormones. When we are about to make a severe bodily effort it is necessary to flood our muscles with blood, so that they may have at their disposal the materials necessary for work—oxygen and blood-sugar, the fuel of muscular engines. At the beginning of a muscular effort the suprarenal glands are set going by messages passing

to them from the central nervous system; they throw a hormone—adrenalin—into the circulating blood, which has a double effect; adrenalin acts on the floodgates of the circulation, so that the major supply of blood passes to the muscles. At the same time it so acts on the liver that the blood circulating through that great organ becomes laden with blood-sugar. We here obtain a glimpse of the neat and effective manner in which hormones are utilised in the economy of the living body. From that glimpse we seem to obtain a clue to that remarkable disorder of growth in the human body known as acromegaly. It is a pathological manifestation of an adaptational mechanism with which we are all familiar. Nothing is better known to us than that our bodies respond to the burden they are made to bear. Our muscles increase in size and strength the more we use them; increase in the size of our muscles would be useless unless our bones also were strengthened to a corresponding degree. A greater blood supply is required to feed them, and hence the power of the heart has to be augmented; more oxygen is needed for their consumption, and hence the lung capacity has to be increased; more fuel is required—hence the whole digestive and assimilative systems have to undergo a hypertrophy, including the apparatus of mastication. Such a power of co-ordinated response on the part of all of the organs of the body to meet the needs of athletic training presupposes a co-ordinating mechanism. We have always regarded such a power of response as an inherent property of the living body, but in the light of our growing knowledge it is clear that we are here dealing with a hormonic mechanism, one in which the pituitary gland is primarily concerned. When we study the structural changes which take place in the first phase of acromegaly,[6] we find that not only are the bones enlarged and overgrown in a peculiar way, but so are the muscles, the heart, the lungs, the organs of digestion, particularly the jaws; hence the marked changes in the face, for the form of the face is determined by the development of the upper and lower jaws. The rational interpretation of acromegaly is that it is a pathological disorder of the mechanism of adaptational response; in the healthy body the pituitary is throwing into the circulation just a sufficiency of a growth-regulating substance to sensitise muscles, bones, and other structures to give a normal response to the burden thrown on the body. But in acromegaly the body is so flooded with this substance that its tissues become hypersensitive and respond by overgrowth to efforts and movements of the slightest degree. It is not too much to expect, when we see how the body and features become transformed at the onset of acromegaly, that a fuller knowledge of these growth mechanisms will give us a clue to the principles of race differentiation.

There must be many other mechanisms regulated by hormones with which we are as yet totally unacquainted. I will cite only one instance—that concerned in regulating the temperature of the body. We know that the thyroid and also the suprarenal glands are concerned in this mechanism; they have also to do with the deposition and absorption of pigment in the skin, which must be part of the heat-regulating mechanism. It is along such a path of inquiry that we expect to discover a clue to the question of race colour.

This is not the first occasion on which the doctrine of hormones has been applied to biological problems at the British Association. In his Presidential address to the Zoological Section at Sheffield in 1910 Professor G. C. Bourne applied the theory to the problems of evolution: its bearing was examined in more detail in an address to the same section by Professor Arthur Dendy during the meeting at Portsmouth in 1911. At the meeting of the Association at Newcastle in 1916 Professor MacBride devoted part of his address to the morphogenetic bearings of hormones. Very soon after Starling formulated the hormone theory, Dr. J. T. Cunningham applied it to explain the phenomena of heredity.[7] Nay, rightly conceived, Darwin's theory of Pan-genesis is very much of the same character as the modern theory of hormones.

[6] See Keith, *Lancet*, 1911, ii., p. 993; 1913, i., p. 305.
[7] Dr. J. T. Cunningham, *Proc. Zoo. Soc. London*, 1908, p. 434.

The following Papers were then read :—

1. *Some Notes on the Finnic Problem.* *By* Harold Peake.[1]

It was formerly believed that the Suomi or Finns, who speak a language with Asiatic rather than European affinities, were a Mongoloid people who had arrived from Siberia. More recently the view has been advanced that they are a people of Nordic type, who have imposed their language upon their Mongoloid neighbours. There is no doubt that the modern inhabitants of Finland contain both Nordic and Mongoloid elements, but the balance of evidence tends to show that the language and tradition are derived from the Asiatic element.

A fresh examination of the archæological evidence seems to show that the first wave of these Mongoloid people arrived in the Baltic region on the retreat of the Ice Sheet, and were responsible for the Maglemose culture, which developed later into that known as East Scandinavian or Arctic. Towards the close of the Neolithic Age the Nordic people arrived in Denmark from the Russian steppes, and there mingled with a remnant of the kitchen-midden people, and perhaps learnt the custom of erecting megalithic tombs from 'Prospectors,' whom they found there searching for amber. The evidence deducible from the skulls of the passage-graves seems to show that these people advanced into Scania and Westergotland, driving before them the Maglemose-Arctic folk, who retreated to the north, where they survive as Lapps.

Meanwhile further Mongoloid tribes were crossing the Urals and advancing up the Volga as far as its junction with the Oka, and were well established there early in the Bronze Age. In the middle of that period they were occupying the margins of the Finnish lakes, and at the same time Nordics from Sweden were occupying the Baltic seaboard.

In the fifth century B.C. the Nordics took to the fjords and to piracy, and there was a general movement to the south and west. Meanwhile the Mongoloid tribes occupied the whole of Finland, the Baltic provinces, and East Prussia. When, about A.D. 1000, the period of piracy ceased, fresh Nordic immigrants arrived from Sweden, who were the ancestors of the present Nordic population of Finland.

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2. *History and Ethnology in Central Asia.* *By* Miss M. A. Czaplicka.[2]

The object of this paper is to discuss the relation between history and ethnology, with reference to the special area of North Central Asia. The modern teaching of history has suffered from an inadequate treatment of its ethnological background : we learn a catalogue of events relating to a branch of mankind, without understanding the racial peculiarities of the mind of that branch. For Central Asia the historians have given us, on the one hand, a list of wars and invasions; on the other, a collection of artistic productions. So far so good; but to each of these the name of a people has been attached, and these names have found their way into handbooks of ethnology as racial terms. Thus such expressions as 'the Mongol race' and 'the Tatar culture' have been popularised, though they rest on nothing more than the names of chiefs, or of clans successful in imposing their chiefs on other clans.

Only by sifting Central Asian history by ethnological methods shall we solve the problems, not only of Indo-European origins, but also of the relation between Asiatic races, and especially between the two great branches, Iranian and Turanian. To work out the ethnology of that earliest and richest history of Central Asia found in the Chinese annals ought to be as much our aim as the working out of the ethnology of ancient Egypt or of Babylon. In the meantime, in order to understand the present racial composition of the greater part of Europe and Asia, it may suffice to analyse the invasions and mixtures which took place from the time of Attila's Huns to the 'Mongols' of Jinghis

[1] Probably to be published in *Journ. Anthropological Inst.*

[2] To be published in *Journ. Anthropological Inst.* : see also M. A. Czaplicka, *Turks of Central Asia* (Oxford, 1918).

Khan. And it may be expedient to try, first of all, to throw ethnological light upon the last great racial re-grouping, which, occurring in the time of Jinghis Khan, may be said to persist to our own day.

Our existing classification for Eastern Europe and North and Central Asia, while professedly ethnological, is based on historical rather than ethnological data. Thus the Asiatic peoples nearest to the Slavs are called 'Ural-Altaic,' because they all crossed the Altai and the Urals on their way to Europe; and in this grouping are included five 'races'—Finnic, Turkic, Tungusic, Samoyedic, and Mongolic—who are said to be linguistically alike but, otherwise, to form separate races. But the 'Mongolic race' cannot be shown to form a distinct group in the same sense as the other four; and its appearance in the same rank with Turks and Finns is due to the ethnologists' uncritical adoption of the history of the Jinghis Khan period. History, however, when used critically helps us to define the real position of the Mongols. Ethnologically they form a bridge between the Tungus and the Turks, originating as they do in a mixture of those two races on the steppes of Mongolia. Hence it is misleading to speak of a 'Mongolian type,' since there never was an original Mongolian type as there was a Tungusic or a Turkic type.

In the same way—by the uncritical adoption of historical data into ethnology—another misleading term, 'Tatars,' has come to rank almost as a racial definition; whereas it is simply a name of Tungusic origin for a clan which at the time of Jinghis Khan belonged to the same confederacy as did the Mongol clan.

Until the real content of these names—Tatar and Mongol—has been disentangled, we cannot hope to reconstruct the racial compromise which took place in Eastern Europe (more particularly on the Upper Volga) between Finnic, Slavonic, and Turkic elements.

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3. *Traces of Polynesian, Melanesian, and Australoid Elements in Primitive America.* *By* Rev. Francis A. Allen.

The writer brought forward evidence to support the view that Melanesian, Polynesian, and Australoid stocks are represented in the native populations of America.

4. *The Physical Characteristics of the Modern Briton.* *By* Prof. F. G. Parsons.

The subject is brought forward in order to collect the opinions and experience of those working anthropologists who may be present as to the most valuable and, at the same time, most practical characteristics of the modern inhabitants of the British Isles.

The following characteristics are suggested for discussion:

(*a*) The Cranial and Cephalic Index.—It is desirable that this opportunity should be seized for making a considered and up-to-date pronouncement as to the working value of this index, and the opener, in spite of anything he has said and written in the past, intends to submit his reasons for believing that, merely in the shape of a bare index, it is a most valuable clue to racial origin.

Stress will be laid on its value in the hitherto largely uncharted field of modern Germany, as well as on the fact that the index of the British Isles is the lowest in Europe.

An attempt will be made to collect and tabulate all the cephalic indices hitherto recorded of the British Isles, and it is hoped that subsequent speakers will be able to point out or fill omissions where they occur.

In this way, if it achieves nothing more, the discussion will justify itself in pointing out to coming workers the places where our knowledge is weakest. The advantages of reinforcing the bare index with a statement of length and breadth averages and of frequency curves will be considered and also the effects which sex and environment exert on the index.

(*b*) The value of the orbital index will be considered, and the orbital

height as a means of discriminating between the Nordic and Mediterranean types noted.

(*c*) The value of the cranial height and facial indices.

(*d*) The value of standardised orthogonal projections of the normæ of skulls.

(*e*) The value of stature and its quick reaction to environment.

(*f*) The value of eye colour and the presence of brown pigment.

(*g*) The value of hair and skin colour and its difficulties. Frequency of red hair as a racial test.

(*h*) The features, especially the contour of the nose.

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5. *A Comparison of an Ancient and a Surviving Type of Man.* By Professor H. J. Fleure.[3]

Geographical study of anthropological types in modern populations has revealed nests of persons resembling in many ways types of pre-Neolithic periods. Among the pre-Neolithic skulls we may isolate the following examples of one type : Brunn, Brüx, Ofnet VI. 21, i, Combe Capelle, and Grenelle (Calotte). To this list may in a sense be added the following, which, however, do not correspond completely in character to the above : Galley Hill, Dartford, Langwith, Chancelade, Obercassel, Halling, Tilbury, Solutré 5, Ipswich, and Liri. Several of the above are of disputable age.

The question of the relationship of the so-called Grimaldi negroids and Barma Grande No. 2 may be raised here. Of skulls of presumed later date we note the Cave Skull B from Macarthur Cave, Oban, and from Arena Candida, Rome.

From Novilara (Iron Age), several skulls have index 66, 67, 68, because the breadth is only 128-129. We may also instance a number of skulls from long barrows in Britain, from certain French dolmens (Bas Moulins and Billancourt) and from Swedish megalithic graves. These seem to show a grading from what we may call Combe Capelle characters to those we call Nordic. In the Combe Capelle skull and related types we find length of skull approaching 200 or more, breadth usually rather under 140, the cephalic index, therefore, being rather under 70. The Basilo-Bregmatic height is slightly in excess of breadth, the glabella prominent, the supraciliaries large, with a sulcus above them but not so much over the glabella, forehead retreating, skull hypsistenocephalic, nasal index over 50, orbit usually low and long, prognathous, 'ellissoide pelasgico.' Some characters we associate with the Nordic Race are higher vaulting of the whole skull, a leptorrhine condition, with a survival of some of the strong, bony development of the previous type.

As regards living persons we have evidence from Somaliland, Abyssinia, and Egypt, from Sardinia, from Tras-os-Montes, Portugal, from North Italy, from the Rhône Valley, from various regions mentioned by de Quatrefages and Hamy such as Austria, Rumania, Russia, and India. Nine clear cases have been studied in some detail in the immediate vicinity of Plynlymon, and five more from the same region closely approach the type. About ten more have been found not far off. These are all men of pure local descent. Several individuals of the type have also been studied on the moorlands in the remoter parts of S.W. Wales. There is thus a strong presumption that we have a persistent type, and it may be hinted that it is a type which has probably contributed a good deal towards the evolution of at least the Nordic and the Mediterranean Races.

The characteristics of this type are those noted above for the Combe Capelle skull, combined with darkness of hair and eyes, prominence of the zygomatic arches, stature rather greater on the whole than that of most Mediterranean types.

We have evidence of the marked occurrence of the type round about 1870 and round about 1840 in Plynlymon district, so it must be truly characteristic of this very remote region.

[3] To be published in *Journ. Anthropological Inst.*

Most of the individuals noticed in Wales have the hair rather straight, with low orbital index and prominence of the zygomatics. But rare individuals with marked prognathism have the hair very curly, and might even suggest a 'negroid character.' The latter character is emphasised by Giuffrida-Ruggeri in the name 'eur-african type.'

WEDNESDAY, SEPTEMBER 10.

The following Papers were read :—

1. *Recent Discoveries of Archæological Interest in the Channel Islands.* *Communicated by* R. R. Marett, *M.A., D.Sc.*

(1) *La Cotte de St. Brelade.*—The excavation of this site, which is entrusted to a Committee of the British Association, was resumed during July and August of this year. A cutting 12 ft. deep has been driven from outside the entrance along the W. wall of the cave, with the object of studying more fully the nature of the cave-filling below the floor of human occupation, the deposit in question being known to contain organic remains. Incidentally, it has come to light that immediately beyond the entrance there existed in Mousterian times a sloping platform, where flint-knapping operations were carried on. Above 500 pieces, ranging in quality from mere workshop refuse to highly finished implements, have already been unearthed here. In the vicinity is a rich rodent-bed which, though it cannot differ greatly in age from the rodent-bed found inside the cave, since Hensel's Banded Lemming is the prevailing species, presents some peculiar features.

(2) *Grotte de la Belle Hougue.*—Near the Point of this name on the N. coast of Jersey a cave has been discovered which, it may be, can claim the rare distinction of containing Pliocene remains, though further research is needed to make the matter certain. A party of Jesuits in 1914 lighted on a small hole in the cliff side through which by means of a rope it was possible to descend into an ancient sea-cave, its mouth completely blocked by falls from the high land adjacent. Their secret was not revealed till 1918, when the Rev. Father H. Morin handed over to the Société Jersiaise such spoils as had been secured in the course of a somewhat perfunctory exploration. These include shells of various species, the most interesting of which is *Astralium rugosum*, at present confined to more Southern waters; and teeth, bones, and numerous pieces of antler belonging to *Cervidæ*, which Dr. Andrews is at present disposed to bring into close relation with *Cervus Etueriarum* and *Cervus Issiodorensis* (Croizet and Jobert), Pliocene deer from Auvergne. These specimens occur in a hard breccia, associated with small stalactites, of unique occurrence in a Jersey cave and geologically puzzling in no small degree. Above the breccia are loose pebbles, and among these, it would seem, and not in the breccia, was found a neolithic celt, which may have fallen from above.

(3) *Dolmen at De Lancy Park, Guernsey.*—The remains of a dolmen have recently come to light here. The massive props, 10 to the N. side and 9 to the S., are *in situ*, but overthrown, while the capstones have disappeared. Pottery in a damaged state, implements and bones were found, but the bulk of the neolithic deposit was doubtless thrown out when the monument was disturbed, presumably in connection with agricultural operations.

(4) Other matters which call for mention are the discovery of what is presumably a sculptured design on a capstone of the Déhus dolmen, Guernsey; the results of a re-examination of the Couperon dolmen, Jersey; and the finding of a raised beach at Crabbé, Jersey, at a height of 155 ft. above mean sea-level, and hence comparable with the raised beach at South Hill recently examined by Major T. E. Naish.

2. *Recent Discoveries in Prehistoric Archæology in Guernsey.* *By* Col. T. W. M. de Guérin.

The recently discovered sculptured human figure on the under surface of the second capstone of the central chamber of the dolmen of Déhus, Guernsey, shows an affinity to the anthropomorphic figures of the late neolithic and aenolithic periods of the valleys of the Seine and Marne and of south-eastern France. Its presence in the central chamber, the first structure to be erected, proves the late date of the dolmen.

F. C. Lukis' account of the excavation of the dolmen showed evidence of its use as a place of burial for a very long period, and of the erection of the four secondary chambers at a later date than the central chamber. The discovery of a copper knife-dagger and two rings points to its use in the aenolithic period.

There is evidence of the worship of the divinity represented by the figure for a very long period in Guernsey, one of the two existing statue-menhirs in the island being probably of the Iron Age.

Evidence proves the existence of trade intercourse between Guernsey and France at the end of the neolithic period and in the Bronze Age.

Joint Meeting with Section C.—See Section C, p. 192.

In the afternoon a Sectional Excursion took place to Dorchester Museum and Maumbury Rings.

THURSDAY, SEPTEMBER 11.

The following Papers were read :—

1. *Death Ritual in Eddystone Island of the Solomons.* *By* A. M. Hocart, *M.A.*

The Eddystone Islanders expose the bodies of their dead in the embryonic position. After the funeral four men catch the soul on a dracaena leaf and a ring, in order to secure the soul's services in divination. The widow may be strangled, but more often she is confined in a small enclosure with her knees drawn up; she may not wear any finery, nor eat of food cooked in the house. On the fourth day a big feast is held, at which a long prayer is recited which enables the soul later on to go to the land of the dead; but in the meantime it goes to wait in the cave at the top of the highest hill. After ten or twelve days the skull is fetched away and put in the sun to bleach. The next event is a small feast called 'Bathing.' On the eighteenth day the skull is put into the skull-house by the mortuary priest, who makes a burnt offering of pudding. On the thirty-sixth day a small feast is held, and four baskets are burnt. On that day the ghosts come to take away the deceased to the land of the dead. Sometimes a séance is held at night to converse with the ghosts, who answer by whistling. Life in the other world is exactly as in this world, only it goes on at night. On the fiftieth day is a big feast, which closes the series for ordinary people. The day before they bury the string on which the days, or rather nights, were counted, and put a basket into the skull-house. For chiefs they have a feast on the hundredth night; then, after a lapse of time which depends upon supplies, they hold the final celebration or Night Festival, which is one of the great functions in Eddystone. In olden days it appears to have been often combined with the great head-hunting feast.

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2. *The Cults of the Mother Goddesses in India.* *By* W. Crooke, *C.I.E., Hon. D.Sc. Oxon.*[1]

The cult of the mother goddess is prominent in Minoan, early Hellenic, Western Asian, and Babylonian ritual. It is suggested that some light on its origin and development may be thrown by the study of the widespread mother cults in India. In Vedic mythology goddesses hold only second rank, and some at least of the modern Hindu goddesses seem to have originated among the non-Aryans who had at a very early period reached the agricultural stage. But it is doubtful if the cult is based on the co-operation of women in agriculture, or that it is connected with Mother Right. It has been the habit to derive all the mother goddesses from the cult of Mother Earth, which is described. But there are other types of goddesses—the Jungle Mothers, deified women, and elemental deities which cannot be readily connected with earth worship. The progress of anthropomorphism is traced from the aniconic to the iconic stage, in the periodical rest and awakening of the mother goddess. Her energies are recruited in two ways : by the rites of the sacred marriage, and by the blood sacrifice, often specially of male victims.

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3. *Badaga Clans.* *By* F. J. Richards.

Part I. *Introductory.*

1. Foreword. Importance of basing the study of a South Indian tribe or caste on a topographical examination of social organization.
2. Affinities and Environment.
3. Physical characters. The Badagas are not an 'autochthonous' jungle tribe, but comparatively recent immigrants from the Mysore country.

Part II. *Social Organization.*

4. Endogamous Groups. Accounts hitherto recorded of the sections of the Badaga community fail to discriminate between endogamous groups and exogamous clans. The Badagas 'proper' and the three 'associated clans.' The five endogamous groups.
5. The Clan Hamlet. The typical Badaga hamlet consists of members of one clan, related to the Badagas of other hamlets either as 'brothers' or 'in-laws.'
6. The Cult Group. Clan hamlets federated into clan cult groups for celebration of agricultural rites.
7. The Nad. Badaga Cult Groups federated into Nads and associated with other endogamous groups of the Badaga community and other Hill tribes for purposes of economic and social autonomy.

Part III. *The Harvest Festival.*

8. Cult Ingredients. Threefold characters. (*a*) Autochthonous element represented by Kurumbar officiant; (*b*) Cult of Tribal Hero Hiri Odiya; (*c*) Cult of the *Lingam* (Mahālinga-swāmi).
9. Ritual. (*a*) Preliminary; (*b*) The incubation in Hiri Odiya's House; (*c*) Puja to (Mahālinga-swāmi); (*d*) Plucking the First Fruits by Kurumbar; (*e*) Clan Feast; (*f*) Ancillary rites; (*g*) Sacrifice, goat and buffalo; local variations.

Part IV. *The Clans.*

10. Distribution of (*a*) Badaga clans; (*b*) associated clans; (*c*) other endogamous groups.

Part V. *Conclusion.*

11. Stratification. The Badaga community exhibits traces of at least two migrations, (*a*) the early Badagas and the Hoysala conquest, (*b*) the Ummattûr conquest and Lingâyat influence. Associated clans apparently intermediate.

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[1] To be published in *Folklore*.

4. *Santiago; The Evolution of a Patron Saint.* *By* HAROLD PEAKE.[2]

The western side of the Iberian peninsula is strewn with megalithic monuments, erected, according to some writers, by early prospectors for metal and other precious commodities. Though their original purpose is doubtful, they became in time objects of veneration, and their worship was prohibited by the Council of Toledo. Among these monuments two, a menhir and a hollowed stone, stood near the port of Padron, and were known as *Patronus* and *Barcha*, 'the skipper and the boat.'

When the Moors had over-run the greater part of the peninsula, the small remnant of Christians left in Galicia needed a war-cry in the Holy War which they waged against the Saracens. They selected Santiago, or St. James, for their patron, and his cult became associated in the minds of the natives with the megalithic Padron or Patronus. In spite of many attempts by bishops and others to dissociate the two cults, including the transference of the shrine from Padron to Compostella, it was found impossible to do so, and the traditional story of St. James gathered around itself many features which belonged to the original megalithic worship.

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5. *Excavations in Cyprus in* 1913.
By Professor J. L. MYRES *and* L. H. D. BUXTON.[3]

These excavations were undertaken on behalf of the Cyprus Museum, with funds granted by the Government of Cyprus, and were designed to supplement existing evidence as to some of the more important problems in Cypriote archæology, as follows :—

(1) In a Bronze Age necropolis at Lapathos on the north coast, a sequence of tombs was obtained covering the 'Early' and 'Middle' Periods of the Bronze Age, and contributing many interesting details to our knowledge of the burial customs and physical types. The usual datemarks showed that the 'Middle' period began not earlier than the Twelfth Dynasty of Egypt.

(2) The late Bronze Age necropolis at Enkomi near Famagusta, already partly excavated in 1895 for the British Museum, yielded few fresh tombs, but a good deal of information as to the history of an Ægean colony on this site.

(3) The well-known 'megalithic' monument near Enkomi, popularly called 'St. Catharine's Prison,' was shown to belong to the historic necropolis of Salamis, and probably to its Græco-Roman stage.

(4) The 'Bamboula' mound in the outskirts of Larnaca was shown to consist of late Greek and Græco-Roman stratified debris, overlying a fortification wall and other remains of the Græco-Phœnician city of Kition. The earliest remains here go back only to the beginning of the Early Iron Age, and the wall, which overlies them, may be as early as the seventh century B.C.

(5) A sanctuary site at Levkoniko yielded a rich and continuous series of Cypriote sculpture beginning in the seventh or eighth century B.C., and passing under successive Assyrian, Egyptian, Hellenic, and Græco-Roman influences. The figures were those of male votaries carrying various emblems of a local deity eventually identified with the Greek Apollo, and illustrating some difficult questions of costume.

(6) The Byzantine site at Lampousa on the north coast near Lapathos yielded only evidence of wholesale quarrying of the older settlements, during the Middle Ages. The Hellenic town of Lapathos has thus been wholly destroyed, and its Byzantine successor has been utterly ransacked by treasure-hunters.

The antiquities from these sites are exhibited in the Cyprus Museum. A full report of the excavations has been delayed by the war, but will be published shortly; and also the results of Mr. Buxton's anthropometric study of the ancient and modern Cypriotes.

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[2] See *Folklore*, xxx, 3, pp. 208-226.
[3] See *Journ. Anthropological Inst.*, Part I, 1920.

6. *The Anthropology of Cyprus.* *By* L. H. Dudley Buxton, *M.A.*

The enquiry into the anthropology of Cyprus was undertaken in the autumn of 1913, under the general direction of Professor J. L. Myres. During the course of the enquiry 557 adult males were measured, and a small number of adult females. A large number of observations on school children were also taken. A number of skulls from bronze age and other sets were collected.

The villages in which measurements were made may be divided into four groups, namely, Group I., the North Coast villages, Lapethos Karabas, Hagios Ambrosios, Akanthar; Group II., Eastern Mesoaria villages, Crihomi Limnea, Hagios Sergios; Group III., Levkoniko; Group IV., Nicosia, Kythria, and various villages in the neighbourhood. Groups I. and II. may be taken as typical groups. The mean head breadth of all groups is similar, viz. 149 mm. In the case of head length two subdivisions occur, viz. those groups with a head length of 182 mm. (typical Group I. 220 males), and those with a head length of 178 mm. (typical Group II. 167 males). The mean head length for Cyprus (557 males) is 180 mm., which seems to show that these two subdivisions are equally divided. It is not improbable that this division may suggest, in view of the large number of observations, that two racial elements are really present, as a difference of 4 mm. appears to be significant. The two divisions do not, however, suggest the orthodox division into Mediterranean and Alpine types, but the matter is not at present sufficiently certain.

It appears, as far as the few skulls examined at present can be counted as evidence, that the ancient types closely correspond to the modern types. The means for both the whole collection of crania and that of bronze age crania are as follows: Cranial length, 177 mm.; cranial breadth, 140 mm. This gives a difference of 9 mm. in breadth between the living and the dead, and a difference of 3 mm. in length between the dead and the living in Cyprus as a whole, but a difference of 5 mm. between the inhabitants of modern Lapethos and Karabas and the ancient inhabitants of the same place. No great change is at present therefore apparent. It is possible that when a greater number of crania are available the two groups, if two groups there be, may be differentiated.

It should be noted in connexion with these facts that most of crania came from places where the largest number of observations upon the living were made, and also that the groups were selected not haphazard nor to fit the figures, but on a geographical basis. It was only after the grouping was made that the possibility of ethnological subdivisions became apparent.

With this series of anthropological measurements another gap in our knowledge of the ethnology of the Eastern Mediterranean has been filled. Several gaps still remain, of which the most important appears to be Southern Anatolia.

FRIDAY, SEPTEMBER 12.

The following Papers and Report were read :—

1. *Stonework and Goldfields in Papua.* *By* E. W. Pearson Chinnery.[1]

The following stone objects have been unearthed, many feet below the surface of goldfields, in the mountainous districts of the interior of Papua by European miners engaged in gold-digging :—

Pestles (some of them carved to represent birds with snake-like heads, and some of them encircled by knobs).
Mortar of granite (surrounded by knobs).
Axe head of obsidian.

Natives have unearthed in one of these goldfields (Yodda) :—

Quartz objects of various shapes with holes pierced through them (these were converted by the finders into stone clubs).
Granite mortar (which holds rain water and is now used as a mirror).

[1] See *Journ. Anthropological Inst.*, Dec. 1919.

On the summit of a large hill in the vicinity of the Yodda goldfield is :—

Large mortar (which holds rain water and serves as a drinking place for natives hunting in the vicinity).

Between the Yodda goldfield and its coastal region, in the Giriwu river :—

Human image (hands crossed on stomach, and forehead retreating to a point at the back of head—unshaped below the waist).

And near the village of Gona on the coast of the Yodda region, in the vicinity of the Giriwu mouth :—

Fragments of ornamented pottery (unearthed).

In the vicinity of Rainu (Collingwood Bay) :—

Fragments of ornamented pottery, obsidian objects, stone pestles, and conus shells ornamented with incised designs (unearthed).

The origin of the above objects is not known to existing inhabitants.

On the South-east Coast, in the vicinity of the old Gibara (or Milne Bay) goldfield, the following stone objects have been noted :—

Stones (with concentric circles chipped thereon).
Short standing stones (with markings thereon).
Circles of stone sitting-places (in some of which cannibal feasts were once held by present inhabitants).

In his book on the Megalithic Culture in Indonesia (1918) Mr. W. J. Perry deals with the movements of a stone-using people who evidently were acquainted with gold-mining and who settled in districts where gold was found. These people left, among other things, as a sign of their presence, terraced irrigation and megalithic monuments.

The evidence of the stone objects in Papua shows that this country also was visited at some time by stone-using people who differed in many respects from the present inhabitants. It would appear from the distribution of the objects that these stone-users had some interest in gold-bearing country; such an intense interest, in fact, that they penetrated the very heart of the interior and left their traces in the places some of which are the actual gold-workings of the present day. Terraced irrigation has been noted in some of these districts.

If the early stone-using people of Papua can be associated with the stone-using immigrants of Indonesia we may reasonably suppose that the motive which led them into the interior was gold-seeking, a similar motive to that which induced the whites to penetrate the same country and overcome the tremendous difficulties in the way.

If this assumption is correct the early prospectors possibly searched for quartz with the object of extracting the gold it contained by a process of crushing, to which use the pestles and mortars would be adapted.

Further investigation of this subject may help to clear up many of the problems of the ethnology of Papua.

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2. *Some Balkan Antiquities Found during the Period* 1915-1919.

By Stanley Casson, *M.A.*

I. *Macedonia.*—Archæological discoveries in the Vardar, Struma, and Langaza valleys and on the Salonika littoral.

(*a*) The prehistoric mounds of Macedonia; their types and the pottery found in them. Incised, pebble-polished and painted wares. Imported wares and foreign influences. Stone and bone implements.

(*b*) Prehistoric burials and cemeteries. The Aivasil and Lower Struma burials. The Chauchitsa cemetery.

(*c*) Classical town sites.

i. Lete.
ii. Berga.
iii. Calindoea.
iv. Amphipolis
v. Thessalonica. The Roman and Greek cemeteries of Thessalonica.

(*d*) Isolated discoveries of the classical period :

i. Sculptures.
ii. Inscriptions.
iii. Earthenware and bronze objects.

(*e*) Various discoveries of the Byzantine period.

II. *Thessaly.*—A prehistoric site in the plain of Larissa near Chasambali.
III. *Doris.*—Dorian town sites in the Bralo area.
IV. *Turkey.*—German excavations in Turkey during the war.

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3. *Recent Discovery of an Unrecorded Type of Circular Earthwork in the New Forest. By* H. KIDNER.

The circular earthwork described in this report is situated on the west side of Hatchet Moor, Beaulieu Heath, about 210 yards east of a trackway running southwards from Pudding Barrow, where another trackway comes in obliquely on the left and crosses (see O.S. map). The earthwork is of a type hitherto unrecorded in the New Forest. The circular bank is slightly over 2 ft. high, and 21 ft. wide; and is continuous the whole way round without gap for entrance. There is neither outer nor inside ditch, nor central mound. Measurement : Bank, 21 ft.+area 102 ft.+bank 21 ft.=144 ft. over all. Diameter of area=34 yards; over-all diameter=48 yards.

The area surface is slightly lower than the ground level, as if depressed; and whilst Iceland moss is found growing outside, none or scarcely any is seen within the area.

Whence the material was obtained for constructing the bank is not apparent, as the difference of level respectively of area and ground surface does not seem to account for all the material. In three bowl-barrows on Ibsley Common excavated by Mr. Sumner the nuclei were composed of white pipeclay brought from a distance of a quarter or half a mile; and he suggests a similar transport of material in the earthwork now reported.

The setting of the earthwork on the open moor in association with bowl-barrows; the width, spread appearance, vegetation and consolidation of the circular bank—all support the conclusion that it is of Bronze Age date. There being no outer ditch nor any gap in the bank for entrance negatives any idea of its being either a camp or stockade of Norman, Saxon, or Roman times.

The earthwork is of the type described by Sir R. Colt Hoare as 'Pond Barrows,' and it differs from a typical disc-barrow in not having either inner ditch or central mound. The writer suggests that the earthwork was primarily, if not exclusively, intended for purposes of religious ritual, and only secondarily, if at all, for sepulchral uses.

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4. *Hedenesbury or Hengistbury of Prehistoric Time. By* G. BROWNEN.

On the western bank of the estuary of the rivers Avon and Stour are the prehistoric (earthwork) northern defences of an important settlement commanding the waterways from the Solent and Channel to the hinterlands of Wilts, Dorset and Somerset and their prehistoric sanctuaries, &c. Portions of these fragmentary mounds have been roughly opened in modern times, with insignificant results, but the Research Committee of the Society of Antiquaries undertook the first systematic exploration of the site a few years since, and its Report was published in 1915.

The township or settlement possessed a port just within the estuary with an acropolis, and has afforded proof of trade with ancient Gaul more than two millenia ago—chiefly by way of the Loire and Garonne. Its traffic reached Marseilles.

Among the many and curious finds obtained was a hoard of some thousands of coins—a few only being Roman and dating from the Republic nearly to the Roman departure from Britain.

The great bulk of the discovered coinage was British and Gaulish in type, and indicate an intimate connection or correspondence with this British port.

The coins mostly appear to have been in good or new condition when hidden, but have become corroded by time, aided by marine and climatic influences on or in the site in the valley.

As nearly all were found in or near one site, the hoard may probably be regarded as belonging to trade, as in a banking establishment or as a subsidy for help.[2]

One other matter arises out of this ancient *entente cordiale*—Are we now able to give this British port a name?

In the Ravenna lists there is a port named Bolvelaunio, which would suit this township very well. Mr. Baxter has placed it at Poole, about ten miles west in Dorset. Gen. Pitt-Rivers locates it at Christchurch, about one mile north on the same rivers. But these towns are English. Objections may be raised to these conclusions in that these sites were not existent in the period required, but later. On the other hand, the Ravenna geographer, who had access to fuller records than we possess, indicates a well-known port township and would harmonise better with the late Sir John Rhys' selection of the river Stour as the boundary line betwixt the Brython and Goidel.

The knowledge and usage of this West Hampshire port is now made evident by these relics found within its area, and is the justification of the strong, though fragmentary, ramparts still remaining on the site.

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5. *Report of Committee on Archæological Investigations in Malta.*—See Reports, p. 123.

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6. *Some Glimpses of Unknown Papua.* *By* E. W. Pearson Chinnery.[3]

Within recent years many communities of woolly-haired people have been discovered during administrative exploration in various swamp and mountain regions of the interior of British New Guinea. It has been noticed that those found in the mountains are distinctly shorter than those in the bush lowlands, who in turn differ physically from the coastal people.

It will be found on further investigation that a Negrito-Papuan element, discovered in the Mafula and described by Williamson, exists also in the tribes of the Owen Stanley Range from Mount Chapman to Mount Obree, all of which appear, physically, to be the results of a mixture between earlier stocks of short and tall, light- (yellow) and dark-skinned peoples. The various languages spoken by these peoples have been classified as Papuan.

Joint Meeting with Subsection I (Psychology), at which the following Papers were read:—

7. *Magic and Science.* *By* Prof. Carveth Read.[4]

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8. *Primitive Art as a Means of Practical Magic.*[5]
By Rev. H. J. Dukinfield Astley, *M.A.*, *Litt.D.*

Primitive Art includes the pictographic work of primitive man, whether in the past or the present.

In the course of artistic history special attention may be drawn to the cave-

[2] See *Cæsar III.* 9, &c.

[3] Cf. *Journ. Anthropological Inst.*, vol. 45, p. 69 (1915, with W. N. Beaver); vol. 49, p. 36 (1919); *Man.* vol. 17, p. 55 (May 1917); vol. 19, p. 72 (Sept., 1919).

[4] The author has in preparation a book *On the Origins of Man and his Superstitions*, to include the subject of this paper.

[5] To be published in *Hibbert Journal*, Jan. 1920.

drawings of Northern Spain and the Dordogne; to the ornamented implements of the Magdalenian Age; to Neolithic Art as shown in the Kivik rock in Sweden; and at later stages to the art of prehistoric Egypt, and of Crete and Mycenæ. Among the primitive races of modern times the drawings of the Esquimaux and the Bushmen may be noted for comparison.

The most life-like and truly artistic examples of the work of primitive man are those produced by the Cro-Magnon people in the Aurignacian Period, and must have been the result of long previous attempts, though we have no specimens of these.

The Prophet Ezekiel describes artistic representations of a similar nature which he saw in a vision displayed upon the walls of an inner chamber in the temple at Jerusalem as an outcome of popular superstition among the remnant of the people left in the city after its conquest by the Chaldeans.

Now primitive artistry varies from the highest perfection, as in the cave-drawings of France and Spain, to examples that appear like the first efforts of children, or to the petrifaction which is exhibited in the conventional art of the historic period in Egypt. But none of the work was done for a purely artistic purpose, or to gratify the æsthetic sense.

It is all based on sympathetic magic.

Thus, just as religion supplied a marvellous stimulus to art in Athens after the Persian wars, and to Christendom in the Middle Ages, so magic, with a more practical aim in view, supplied a similar stimulus to the artistic instinct which is an inseparable factor in the complex nature of man.

It may be said, This will explain the drawings of animals and such-like, but how explain such drawings, for example, as those of the Dancing Women in the Cave of Cogul? The identical principle applies here also: To primitive man the image or symbol is the same thing as the living actor, and what is represented as being done by the symbol is as though it were being actually performed by the producer of it; compare the Ushabtis in Egyptian tombs and the magical ceremonies of the Australian and other native tribes in the present day.

It is possible that we may find evidences of Totemism, as the basis of social arrangements, either actual or decadent, throughout the peoples whose art we are discussing.

Section I.—Physiology.

President of the Section: Professor D. Noel Paton, M.D., F.R.S.

TUESDAY, SEPTEMBER 9.

The President delivered the following Address :—

An Aspect of Protein Metabolism.

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I. Introduction.

Perhaps at this, our first meeting after the Great War, I might be expected to speak of the part which Physiology played, not only in the alleviation of suffering among the combatants, but also in guiding the policy of the Government as regards the regulation of the supply of food for the civilian population in those dark days when the submarine menaced our very existence.

But so much has already been said upon these matters, and the claims of Physiology have been so amply established, that I have decided to refrain from elaborating them further, and rather to allow myself to forget these past horrors and to ask your consideration of one of these problems of physiology, which is not at present of any apparent practical importance.

I do so the more willingly because I think that at the present time the utilitarian aspect of science is being allowed to take too predominant a position. We are perhaps just now apt to forget that our prime function is the pursuit of knowledge for its own sake. On this all real progress depends.

To find oneself President of a Section of the British Association is an intimation that one has joined the ranks of the veterans and a warning that one's days of active work are drawing to a close.

But, while one accepts the situation with some twinges of regret, one is consoled by the thought that a long association with physiology has enabled one to take a wider general survey than one did in one's younger days, to see more clearly the bearing of one part upon another and to recognise some of the dangers to which we, as investigators and teachers, are exposed.

It has often been urged that physiology, the study of Life, cannot possibly be an exact science in the same way as are physics and chemistry. My old friend, Prof. P. G. Tait, used to twit me with the possession of a mind 'debauched by the so-called science of biology.'

I am not quite sure what the charge that biology is not an exact science really means. But if it means that in it direct methods of measurement are not possible, then I am inclined to reply that in many of the phenomena of molecular physics, including chemistry, such direct methods are still wanting, or have only recently been devised, while in physiology the whole trend of the science has been to devise graphic or self-registering methods, and to exclude more and more the fallacies of observation through the senses. It is only when our study of life involves, as it must often involve, the consideration of consciousness, that we are thrown back upon observational methods, that the personal element is introduced as a disturbing factor, and that our results are open to many different interpretations. Of course the same fallacy may invade the investigation of many of the vital manifestations not involving consciousness, but the fault then is in the observer. It is so difficult to avoid forcing the interpretation which appeals to us. But it should be recognised that the evidence, when set down quite simply and without comment, should lead others to the same conclusion as that to which we have arrived. We are not justified in dressing it up in order to secure it more ready acceptance. In doing so, we cease to be scientific men and become special pleaders.

Yet this dressing up of one's view so as to make it convincing is one of the most tempting of crimes—a crime which all of us, usually unconsciously, have doubtless committed in our time and will go on committing. And the worst of it is that the abler the exponent, the greater is the harm done. Every part of physiology affords startling examples of this. That which first occurs to me is the theory of secretion of urine, upon which a recent writer frankly takes up one hypothesis and with great ability defends it through many pages, as a conclusion to be unreservedly accepted. It is so difficult to say, 'the evidence is inconclusive, to give the verdict of "Not proven."' The same thing is seen in the old fight between the exponents of the two main theories of colour vision, neither of which is necessarily right. An attractive interpretation, boldly stated by an able advocate, is apt to seize the imagination even of a critical physiologist and to lead to an abrogation of judgment and a blind acceptance. Especially is this the case when the work is not in our own special line and when it is announced by a due flourish of trumpets and is supported by the invention of more or less incomprehensible Greek words devised by some classical colleague. Dangerous and unscientific as is this championing of one interpretation of a series of observations or experiments, it has not infrequently helped forward the advance of knowledge. It has often stimulated other workers and led to the true solution of the problem—witness the fascinating work and the able deductions drawn from it by Heidenhain on lymph formation which stimulated Starling to subsequent investigations thus leading to a better understanding of the facts which Heidenhain had observed. Witness too the admirable study of cutaneous sensibility by Head, Sherwen and Rivers and their interpretation of the results, uncritically accepted by some, but which stimulated others to restudy the subject and to indicate simpler interpretations of the observations, and these have reacted again to induce further work upon the problems.

A consideration of these dangers in the physiological inquiry helps us to understand how seldom any line of investigation goes straight to the goal: a zigzag forward progression is almost universal—at one time many points off the straight line in one direction—at another just as many off in another.

This devious mode of progress, perhaps more marked in the work of previous generations, is still manifest in many of the modern lines of advance, largely as a result of too ready acceptance of the conclusions arrived at from insufficient experimental data. Witness the to-and-fro swing of our conception of the significance of adrenalin in the body. The older workers were so hampered by insufficient methods that many of the conclusions accepted as final should have been taken as simply provisional.

II. Protein Metabolism.

A consideration of the present position of our knowledge of the metabolism of protein in the body, and of the way in which we have arrived at it, is a striking illustration of this zigzag advance, what I have elsewhere described as tacking to windward.

It was only towards the end of the eighteenth century that the true nature of the nitrogenous constituents of plants and animals was recognised, although Boerhaave in 1732 had indicated their identity. Fourcroy and Scheele and Berthollet did much to advance our knowledge of their composition.

1. Proteins as a Source of Energy.

It was Liebig, early in the nineteenth century, who really first emphasised the primary importance of the albuminous constituents of the body. It was he who first clearly taught the value of these proteins as constituents of the food in building up the living body. It was he who first pointed out that by their combustion in the body the energy required for work is liberated—although he made the mistake of concluding that it was all supplied by proteins.

Is it to be wondered at that in those days of inadequate knowledge of physiology and of imperfect methods of investigation, he had to content himself with a purely theoretical consideration of the subject, and that he failed to disabuse his mind of the idea of the necessary co-operation of some vital force or spirit to protect the albumin from oxidation during the resting state of muscle? Physiologists even at the present day are too apt to seize upon such metaphysical abstraction as a cloak for ignorance!

The formulation by Liebig of the theory that the oxidation of proteins is the sole source of the energy liberated in muscular work is perhaps the most striking example of the danger of the bold statement by a great scientific authority of a conclusion unverified by experiment. For years it dominated all study of the physiology of nutrition and to the present day it influences the practice of trainers of athletes. It was in vain that Voit recorded his experiments, which showed that muscular work does not increase the output of urea, which it should have done had Liebig's theory been correct. Certainly Voit's experiments were themselves imperfect, since he failed to carry his observations beyond the day in which exercise was taken.

It is a striking commentary on the credulity of physiologists that the experiment which struck the first blow at the general acceptance of Liebig's teaching was that of Fick and Wislicenus in their ascent of the Faulhorn, an experiment which for years held a prominent place in every textbook of Physiology, an experiment which every physiologist of to-day will agree was absolutely worthless, inasmuch as these observers took protein food on the day before the experiment and were excreting its products next day, inasmuch as they stopped collecting the urine on the night of the ascent, and inasmuch as their estimation of the work done left out of consideration the respiratory disturbances in the ascent.

Still, I remember how, as a student, I was taught that this experiment had overthrown the teaching of Liebig. Its influence is shown by the fact that Pflüger took up the defence of Liebig's teaching. You all remember the records of the very lean dog fed on the leanest horse-flesh in Bonn and doing work in drawing a load the energy for which was liberated from proteins—because the dog had nothing else from which to liberate it!

You all remember the well-known experiment of Argutinsky by which he thought to show that over 90 per cent. of the energy of the work of hill-climbing came from proteins. At that time I ventured to point out that

Argutinsky was losing weight even before the exercise, that he was in a condition of semi-starvation and that therefore, when any extra call for energy was made, it had to be got from the protein of the body, since he was a lean young man. The chief value of his work was in showing that any increased excretion of nitrogen occurs, not on the day of the exercise, but on the two succeeding days.

Since that time the methods of investigating the processes of metabolism have enormously advanced, and the combination of the study of the respiratory exchange with determinations of the excretion of nitrogen has enabled a definite decision to be obtained as to the utilisation of the three proximate principles during rest and during muscular work. As everyone knows, it has been demonstrated that while carbohydrates must be considered as the most readily available food of the body, it is equally true that the direct or indirect oxidation of the amino acids formed from the proteins of the food or of the tissues on the one hand and of fats on the other are also valuable sources of energy.

2. Proteins in Growth and Repair.

The advance in our knowledge of the way in which protein is used in the construction and repair of tissues shows a less devious course. First came the recognition of changes of the crude protein of the food to more diffusible, and, as was later shown, simpler molecules. Then came the discovery by Kutscher, Seeman and Cohnheim of the more complete breakdown into the constituent amino acids, a recognition of the purpose of the breakdown to yield the constituent "building stones" for use as required by each tissue, and lastly the elaborate work upon the special significance and potentialities of each of these.

Some of these amino acids must be supplied as such, and if certain of them, which may occur only in minute amounts in the body tissues, are withheld, growth is rendered impossible. They become the limiting factor.

Other amino acids, glycin for example, may be formed in the body.

Not the least important of the amino acids are the diamino acids, lysin, histidin, and arginin, which are so abundant in the protein which is combined with nucleic acid in the nuclei of cells. That lysin is essential for growth has been for long well established. Histidin and arginin resemble one another closely in the constitution of their molecules, but while histidin has the iminazole ring, arginin has the guanidin molecule as the end of the chain.

Experiments recorded by Ackroyd and Hopkins [1] tend to show that in the absence of these two diamino acids growth of young white rats is arrested, and that there is a loss of body weight, but that the addition of both or either of them is sufficient to restore the rate of growth. Such observations seem to indicate that they are among the amino acids which are essential and which must be supplied in the food.

The fact that the addition of either one or other is sufficient to restore growth led these investigators to suggest that in metabolism each can be converted into the other. The safer conclusion appears to be that both of them can yield some substance which is necessary for growth and for normal metabolism.

The same workers further give experiments to show that in the absence of these substances, the excretion of allantoin falls and that it is again increased when one or other or both are added to the diet. They suggest that arginin and histidin probably constitute the most readily available raw material for the synthesis of the purin ring in the animal body. It must be remembered that Abderhalden and Julius Schmidt failed to get evidence of the formation of allantoin from histidin in the dog. As yet the relationship of these bodies to purin metabolism cannot be considered as definitely established. Investigations upon birds which excrete such large quantities of purin nitrogen should yield more conclusive results.

The possible source of creatin, methyl-guanidin acetic acid, from histidin has been considered by Ditmann and Welcker on purely theoretical grounds which need not now be considered.

Arginin is a much more abundant constituent of most proteins than is histidin. The characteristic of the arginin molecule is the presence of guanidin. It is guanidin-α amino δ valerianic acid.

In the protein of ox-flesh it occurs to the extent of about 7 to 11 per cent., so that taking the protein of muscle at 20 per cent., there is present in ox-flesh some 2 per cent. of arginin. This contains about 40 per cent. of guanidin, so that in the arginin alone there is no less than 0·8 per cent. of combined guanidin and 5·07 per cent. guanidin nitrogen, or, taking the total nitrogen of flesh at 3·7 per cent., some 15 per cent. of the total nitrogen, or on the lower analysis about 11 per cent.

From cat's muscle Miss Henderson [2] recovered an average of 0·56 per cent. of total guanidin, *i.e.*, 0·4 per cent. guanidin nitrogen, with 3·7 per cent. of total nitrogen in the muscle. The guanidin nitrogen amounted to nearly 10·4 per cent. of the total nitrogen.

3. Specific Action of Constituents of Proteins.

An important aspect of the metabolism of proteins is the physiological activity of some of their products of disintegration.

Their specific dynamic action in stimulating the rate of metabolism and increasing heat production, first demonstrated by Rubner, has been shown by Lusk to be due to the action of their constituent amino acids.

Some of Mansfield's work strongly suggests that this action may be controlled by the thyroid gland, but into this question it is impossible to enter at present.

The possible importance of one product of disintegration of protein, the guanidin moiety of the arginin molecule, has so far received no attention.

i. *Sources.*

Its real significance has been too readily ignored on account of the demonstration of the formation of urea in the metabolism of arginin. But while Kossel and Dakin [3] showed that this urea formation goes on in the liver, they did not find the same evidence of the change in muscle. Thompson,[4] after the administration of arginin by the mouth and subcutaneously to dogs, recovered very varying amounts in the form of urea and got a marked increase in the excretion of ammonia. He was forced to conclude that arginin stimulates nitrogenous metabolism, in this way acting as the more recent work of Lusk has shown that so many amino acids act, and rendering any conclusion as regards the complete conversion to urea impossible.

More recently Inouye,[5] in perfusion experiments through the liver and in autolysis experiments, has observed an increase in creatinin after the addition of arginin.

Thompson,[6] shortly before his tragic and untimely death, published a series of experiments which proved fairly conclusively that arginin alone, and still more markedly when given along with methyl citrate, distinctly increases the output of total creatinin, mainly by increasing the output of creatin.

In the face of such experiments it must be concluded that a certain part at least of the guanidin moiety of arginin escapes conversion into urea and ultimately forms creatin.

That the guanidin in arginin, creatin and other substances may be primarily formed from non-guanidin nitrogen was demonstrated by Burns [7] in the developing chick. He found that the amount of guanidin in the egg showed a steady increase to the twelfth day of incubation and only after this date did creatin appear. In considering the possible origin of the guanidin thus formed, one is almost forced to look to the cholin part of the lecithin molecule as the only possible source. The formation of guanidin or at least of creatin, methyl-guanidin acetic acid, from cholin is not purely hypothetical, for Riesser [8] has not only considered it on theoretical lines—that it can be produced by a union of cholin with urea—but he has actually adduced evidence to show that in rabbits the creatin of muscle is increased after administration of cholin.

Baumann, Hines and Marker [9] in a short note state that by perfusing with choline and urea in the dog, they got an increase of the creatin in muscle.

If cyanamid instead of urea took part in the reaction methyl-guanidin might be directly formed, the ethyl group of the cholin being oxidised away and two methyls removed.

Of course in mammals, and in the chick after hatching, the arginin, in the protein of the food and the creatin in the flesh, when it is eaten, must serve as an ample supply of guanidin, so ample in fact that probably a very considerable part of arginin is at once decomposed by arginase into urea.

ii. *Methyl-guanidin a normal constituent of the body.*

Methyl-guanidin is a normal constituent of flesh and of liver as was shown by Smorodinzew. Miss Henderson [10] found in the muscle of cats an average of 0·0839 per cent. of free guanidin or methyl-guanidin. It occurs in normal human urine and in that of the dog and horse.[11] In the blood of normal dogs it is present in hardly detectable quantities.[12]

In tetania parathyreopriva the increase in the guanidin content of the blood is accompanied by an increased excretion in the urine, and a similar increase in the urine has been found in the idiopathic tetany of children. In two cases of tetany in adults Sharpe found guanidin as di-methyl-guanidin in amounts easily demonstrable in the urine.

Methyl-guanidin like uric acid thus seems to be partly excreted as such and partly, when in larger quantities, to undergo some change.

iii. *Physiological Action of Guanidin.*

Guanidin and its methyl derivative, which in future I shall speak of together as guanidin, are substances of great pharmacological activity. Their action was first investigated by Gergens and Baumann in 1876. They described in frogs fibrillar twitching of the muscles due to a peripheral action and tonic extensor spasms due to an action on the spinal cord. They point out that in mammals the tonic spasms are more marked than the fibrillar twitching of the muscles.

Subsequent investigators have confined their attention chiefly to the peripheral action and considerable discussion has arisen as to the exact point of action of the substance.

When we were investigating tetania parathyreopriva, Burns was engaged on a study, following up the suggestion of Pekelharing, of the possible relation of the guanidin part of the creatin molecule to the tone of muscle. The extraordinary similarity of the symptoms produced to those of experimental tetany suggested to us the possibility that the condition of tetany might be related to some disturbance of the guanidin metabolism, and led to a more careful investigation of the action of guanidin and methyl-guanidin.

We have already arrived at the conclusion that tetany is due to a toxic substance in the blood, since the symptoms can be temporarily removed by bleeding and transfusing with normal sodium chloride solution, a fact which cannot be explained on the view that the symptoms are due to a decrease in the calcium of the blood as had been suggested by McCallum.

We found that the administration of guanidin and methyl-guanidin produced symptoms identical with those of parathyreoidectomy. There was the same direct stimulation of the outgoing spinal neurons to the muscles leading to tremors, jerkings and general convulsions and when large doses were directly applied to the spinal cord a paralytic condition similar to that which sometimes supervenes in tetania parathyreopriva. There was the same increased excitability of the nerves to electrical stimulation, followed, after large doses, by a curare-like action, a condition also observed in clinical tetany after convulsions.

Koch had described the occurrence of guanidin with other bases in the urine of the dog after removal of the parathyreoids. In our series of experiments Burns and Sharpe found a most marked increase in the guanidin or methyl-guanidin content of the blood (*loc. cit.*). The method is long and tedious and there is considerable chance of loss, although in test analysis it was found to give a good return of the added base. But the differences between the guanidin content of normal blood and of blood after parathyreoidectomy and in children suffering from tetany was found to be very marked.

Wishart [13] further found that the muscles of the frog immersed in the serum from the blood of dogs and cats after parathyreoidectomy frequently manifested the tremors and the characteristic change in contraction which are produced by the action of guanidin. The possibility of using this biological

test is, however, limited by the fact that the muscles of frogs kept in confinement for some time do not respond to guanidin as was shown by Langley.

The conclusion we draw from our experiments is that the parathyreoids in some way as yet unknown regulate the metabolism of guanidin in the body and that in doing so they may play a part in regulating the tone of the skeletal muscles.

It is by the continued activity of the efferent neurons of the cord that this tone is maintained, and it is upon these that guanidin acts. Possibly, when the amount of guanidin is small, this action is facilitated by the increased excitability of the nerve endings, and, when the amount is further increased, the effect of its overaction upon the cord may be masked by the onset of the curare-like action on the terminations.

This is not the place to discuss the question of the nerve channels by which impulses concerned in the maintenance of tone reach the muscle.

iv. *Detoxication of Guanidin.*

As I have already indicated, guanidin remains active after methylation, but when it, or its methyl compound, is linked to acetic acid, as in creatin, it becomes inert. Burns has also found that linked to glucose it loses much of its toxicity, and the Camis states that solutions of guanidin become inert when rubbed up with muscle.

I have all along felt that the significance of creatin must be looked for in its guanidin moiety. Creatin itself is inert, although Maxwell [14] has recorded an exciting action in the cortex cerebri.

In spite of Pekelharing's results I do not think that there is evidence that the creatin content of muscles is associated directly with the maintenance of muscle tone. Certainly when the nerve to a muscle is cut, the tone is at once lost, and yet, until the marked structural changes of advanced degeneration appear, Cathcart, Henderson, and Noël Paton [15] find that the creatin content does not markedly decrease.

While freely admitting the validity of much of the evidence that an increase in tone may be accompanied by an increase of the creatin content of the muscles and an increased excretion of creatinin, there seems to me to be no indication of how the increase in creatin modifies the tone. The administration of creatin subcutaneously does not do so. And hence the only possible explanation must be that the increased tone is associated with an increased amount of guanidin in the blood and that the increase in the creatin is secondary to this—the result of an attempt to remove any excess of guanidin. The evidence in favour of this will be presently considered.

As regards the relationship of creatin to guanidin, two possibilities have to be considered, either (1) that creatin is the source of free guanidin, or (2) that creatin is formed to fix an excess of guanidin and to detoxicate it. It may then be excreted as creatin or creatinin, or the creatin may be used in the resynthesis of such molecules as arginin or histidin.

1. The view that creatin is a source of methyl-guanidin is favoured by the ease with which it is oxidised outside the body by HgO to methyl-guanidin. But, on the other hand, there is no evidence that this occurs in the body. Even in large doses creatin is non-toxic and I have found that when injected into parathyreoidectomised animals it does not accelerate the onset of symptoms, while the injection of even very small doses of guanidin does so. If creatin were a source of guanidin it should act in the same way.

2. The second view that creatin fixes and detoxicates guanidin is supported by the following evidence :

1. Miss Henderson [16] finds that after parathyreoidectomy there is an increase of the creatin content of the muscle and a decrease, not only of the free guanidin, but also of the total guanidin along with the increase of free guanidin in the blood recorded by Burns and Sharpe. The decrease in the free guanidin corresponds closely with the increase in the creatin guanidin and suggests that a process of linking is occurring. But on the other hand the more marked fall which occurs in the total guanidin of muscle in proportion to the total nitrogen seems to show that there is either (1) an increased elimination of

guanidin from the muscle to the blood, or (2) a decreased taking up from the blood. In either of these ways the concentration of guanidin in the blood necessary to enable it to manifest its stimulating action on the central nervous system might be brought about. These observations must be repeated as the amount of muscle available for analysis was too small to give absolutely reliable results as to the amount of guanidin. As is well known muscle takes amino acids from the blood and stores them at a higher concentration. Folin has shown that it also takes up creatin and urea, and Mrs. Cathcart has shown that it even takes ammonia salts from the blood.

2. Jaffe[17] had shown that glycocyamin, guanidin acetic acid, is methylated in the body and so converted to creatin. This was confirmed by Dorner.[18] But neither of these succeeded in getting an increase in the creatinin of the urine after the injection of methyl-guanidin. As Riesser points out the toxicity of this substance makes it difficult to get results in this way.

Thompson,[19] however, got a distinct increase in the creatinin output in the dog and in the creatin output in the duck after parenteral injection of guanidin carbonate.

Some recent unpublished work by Wishart carried out this summer in my laboratory shows that after injecting guanidin into dogs and hens the creatin content of the muscle is markedly increased.

I give a tabular view of his results :

Creatin per cent. in muscles before and after injection of guanidin sulphate.

—	Before	After	
Cat 1	·470	·566	
„ 2	·589	·639	
„ 3	·540	·553	
Dog 1	·324	·393	
Hen 1	·460	·426	Control—No guanidin injected
„ 2	·522	·672	
„ 3	—	·643	
„ 4	—	·626	

These observations seem to me to be of very great importance since they indicate quite clearly that creatin may be formed from guanidin.

This formation of creatin from guanidin may explain the failure to recover all the base when it is injected even although it is a substance which resists so strongly the action of oxidising agents.

Pommerenig found that guanidin given in small quantities was completely excreted as such in thirty-six hours, but that in large doses only 30 per cent. was recovered.

Burns (*loc. cit.*) after the intra-muscular injection of 0·64 grm. of guanidin hydrochloride, recovered in the next seventeen hours only about 25 per cent., more than half of which had become methylated.

That the whole process of the formation of creatin is carried on in the muscles and that the liver has absolutely nothing to do with it may now be considered as quite definitely settled. Experiments recorded by Mackie and myself[20] on the effects of exclusion of the liver from the circulation in geese and ducks seem to be conclusive on this point, and they are confirmed by the result of Towles and Voegtlin.[21]

Significance of Urinary Creatin.

As Folin and others have clearly shown, the power of storing creatin in muscle is very limited, and any excess in the food is apt to appear in the urine either as creatin or possibly to some extent as creatinin.

In a man of 65 kilos, the skeletal muscles weigh about 30 kilos, with, say, 0·3 per cent. of creatin, in all some 90 grms.

If anything like 1 grm. of creatin be given it tends to appear as such in the urine.

The taking of even a moderate amount of flesh leads to the appearance of creatin in the urine and although, as Orr and Burns [22] have shown, the creatin is not necessarily all derived from the creatin of the flesh but probably from some other precursor, nevertheless a considerable amount comes directly from creatin. Evidently the power which the body possesses of dealing with creatin is very limited.

At present I do not intend to discuss the question of the possible conversion or non-conversion of creatin to creatinin. It has been an unfortunate battle because it has drawn attention from the much more important question—what is the significance of creatin?—the question on which I have tried to throw a fresh light in considering its relationship to guanidin, but one which has to be further prosecuted in order to decide whether creatin is simply a waste product on the way to excretion or whether it may be used in the body.

To me it seems that these questions may best be solved by their study in animals in which they are least complicated by the creatin-creatinin controversy. Fortunately in birds, as was long ago shown by Meissner, we have a group of animals which excrete creatin as an end product and only at most traces of creatinin. This I confirmed in 1910 [23] and it has been further confirmed by Thompson. Just as their power of changing uric acid to urea is small so that most of their nitrogen comes away in the first form, so their power of changing creatin to creatinin—if it is possessed by any animals—is negligible.

The results then obtained seemed to show that creatin injected subcutaneously does not undergo any change in the avian body, but that it is excreted as such. In three experiments, creatin injected under the skin appeared in the urine to the extent of 91 per cent., 109 per cent., 83 per cent. Such observations do not, however, prove that the creatin formed in the ordinary course of metabolism is all excreted in this form.

Since creatin is at least ten times more abundant in muscle than in any other tissue of the body, and since muscle so greatly exceeds all other tissues in bulk, muscle must be considered *the* source of urinary creatin.

The amount of creatin daily excreted must be the result of the liberation of so much creatin from the muscles, and since the amount of creatin in muscle is so constant, this liberation must be covered by a corresponding formation, or by a corresponding decrease in the bulk of muscle.

It is well known that in fasting mammals creatin appears in the urine, and that in the fasting condition in man the combined excretion of creatin and creatinin shows a comparatively small change in spite of the decrease in the rate of protein catabolism as indicated by the excretion of total nitrogen. In the rabbit on the other hand Dorner's results show an increased total protein catabolism with an enormous increase of the excretion of creatin and creatinin due almost entirely to the creatin.

In geese and ducks I found that there is a rise in the excretion of creatin during fasting which varies with the condition of nutrition of the bird, being small where the nutrition is good at the beginning of the fast and larger where the animal has been on a low diet and is thin before the fast starts. Thus in a young, well-fed goose during a fast of three days there was practically no change in the excretion of creatin, while in a poorly nourished bird fed on maize the creatin excretion on the second day of the fast had increased sevenfold.

Myers and Fine [24] from their observations upon fasting dogs come to the conclusion that the increased amount of creatin execreted during a fast is all derived from the creatin which was in the flesh at the commencement of the fast. They find in short fasts a slight increase in the creatin content of muscle and in longer fasts a decrease. A series of unpublished analyses made for me by Cathcart of the muscles of the salmon kelts and of feeding salmon show that after the prolonged fast of many months the creatin is increased in relation to the total nitrogen of the muscle.

Creatin and Total Nitrogen in Muscle. Thick and Thin of Salmon.

5 Salmon (feeding).

Total Nitrogen.		Creatin.	
Thin.	Thick.	Thin.	Thick.
3·57	3·61	0·241	0·224
		Creatin T.N. 6·7	6·2

5 Kelts (prolonged fast).

3·13	3·18	0·241	0·279
		Creatin T.N. 7·7	8·7

Myers and Fine's conclusions have been severely criticised by Stanley Benedict and Osterberg.[25]

These investigators maintain that creatin is a material which is being constantly formed during the course of a fast, that only that part which is not metabolised is excreted and that the amount excreted is no index of the amount of muscle tissue catabolised. They base their conclusions upon experiments upon dogs rendered completely diabetic by phloridzin. Having shown that during fasting such dogs excrete large amounts of creatin—as had been already demonstrated by Cathcart and Taylor—they gave washed fibrin or washed flesh, both creatin free, in sufficient quantity to nearly cover the loss of nitrogen, and because the creatin excretion under these conditions was still maintained they conclude that it is not the result of the breakdown of muscle tissue. Certainly when these proteins are given an abundant source of the guanidin required for creatin formation has been furnished, and it appears to me to be no proof whatever that in fasting the creatin in the urine is not the result of the catabolism of muscle setting free a proportionate amount of creatin.

But it raises another and very interesting question: granting that the creatin is liberated by muscle breakdown why does it appear in the urine in the absence of carbohydrates and in conditions of imperfect oxygenation of the blood? This question will be dealt with later.

In 1910 I looked upon creatin as part of the muscle molecule—if one may be allowed to use such a term—and considered that the amount of creatin excreted was a measure of muscular disintegration.

This view that creatin is an integral part of the muscle molecule and that it is liberated only upon death has now been adopted by Folin.[26]

The evidence is by no means conclusive. The only experimental work recorded is that of Urano which cannot be considered as in any way satisfactory.

Some recent experiments as yet unpublished by Wishart tend to show that the creatin exists as such in the muscles, and not as an integral part of its substance. In these experiments a frog was killed by a blow on the head and instantly one hind leg still *in situ* was frozen hard in a mixture of ice and salt and the whole of the extraction process carried out near the freezing point up to the hydrolysis of the filtrate. The difference in favour of the unfrozen muscle was comparatively small. Further experiments on the subject are in progress

Frozen.	Unfrozen.
·070	·076
·063	·072
·058	·071

Folin's demonstration of the accumulation of injected creatin in muscle also seems to me to indicate that in part at least it may exist in a free state.

It may well be that in fasting, when the muscle proteins are used as a source of energy or are carried to more essential organs, the free creatin may be liberated proportionately to the break-down and excreted without the reduced muscle tissue showing any percentage decrease.

In 1910 I argued against the possibility of there being an increased production of creatin in fasting and I still think the argument is valid. Since the creatin nitrogen must come from somewhere, any increase in the excretion of creatin should be accompanied by a decrease in the excretion of nitrogen in

other forms. This is not the case, in fact the relationship is in the opposite direction—the increase of creatin being accompanied rather by an increase in 'other nitrogen.'

On the other hand, I then failed to appreciate the possibility that the increase in the creatin might be the result of a failure of its metabolism in some other direction.

Neither Folin nor any other worker has found an immediate increase in the nitrogen excretion after the administration of creatin, and it thus seems unlikely that any metabolic change occurs in it *when about to be excreted.* But its metabolism may be in the process of anabolism, and I shall later adduce evidence that creatin may be used in the building up of the muscle material, e.g., as a source of the guanidin in arginin.

But whether the increased excretion of creatin in fasting is due to its liberation from muscle substance as it breaks down (Myers and Fine), or to its being a product of the disintegration of muscle substance (Folin), or to there being a failure to resynthesise the creatin into muscle substance, the amount of creatin in the urine will indicate the amount of muscle disintegrated and not resynthesised, i.e., *the actual break-down of muscle.*

Three conditions may occur in the course of a fast:

1. The break-down may involve not only muscle but also the proteins in other tissues of the body.

2. It may involve muscle almost exclusively.

3. It may involve muscle, but the nitrogenous constituents may be used for the repair of other tissues, as is so well seen in the fasting salmon, where materials from the muscles are transported to and laid down in the growing ovary.

The first condition occurs in the early days of a fast, especially in well-fed animals where the liver and other organs are rapidly losing weight.

The third condition appears later in a fast when all surplus protein has been metabolised, and when the organs essential to life have to be kept going at the expense of the muscles.

The muscles of the goose or duck contain about 0·134 per cent. of nitrogen in creatin and 3·6 per cent. altogether. Hence, in the break-down of muscle, one part of nitrogen must be in creatin for twenty-seven parts of total nitrogen.

If the nitrogen of the urine is in this proportion, it is muscle tissue which is bearing the brunt of the disintegration due to fasting.

If the total nitrogen is above this proportion to the creatin nitrogen, the protein-rich tissues other than muscle are taking their share in the catabolic process. If the creatin nitrogen is above this proportion, then the conclusion seems inevitable that the nitrogen of the proteins of muscle is being retained and used for the maintenance of non-muscular tissues. This method I applied to the study of the metabolism in the course of fasting in geese and ducks, and showed how it gave direct information of the condition of the exchanges in the body.

Its application to the study of the progress of protein metabolism in fasts in man and other mammals does not necessitate the adoption of any theory of the relationship of creatin to creatinin.

Folin's most recent view[26] of the sources of these two substances is that creatinin represents the ordinary wear and tear of muscle, but that when muscle tissue dies the creatin is set free as a post-mortem product, and that in times of stress, *e.g.*, in fever, fasting, etc., the break-down into creatinin is accompanied by a break-down into creatin. He even admits the possible conversion of small amounts of creatin to creatinin and vice versa.

Accepting this conception, it is manifest that the creatinin and creatin excretion should in the mammal give the same index of the course of metabolism in fasting, as the excretion of creatin alone does in the bird. This I illustrated in 1910 by applying the method to the study of several recorded facts in man.

Creatin as an Anabolite.

The evidence as to whether creatin is a possible anabolite, whether it can be used for the reconstruction of muscle substances, may now be considered.

It was Folin who first suggested that it may act in this way, or, as he put

it, may act as a sort of food. He arrived at this view on account of the disappearance of creatin when fed by the mouth; but the demonstration by Mellanby and Twort[27] that creatin is broken down in the alimentary canal, deprives these experiments of much of their value.

Lefmann[28] after subcutaneous injection in dogs, recovered only a small amount of creatin in the urine, and although his conclusion that there is no conversion to creatin has been criticised by Van Hoogenhuyze and Verploegh, there seems to me to be an increasing amount of evidence in favour of Folin's theory of the utilisation of creatin.

Cathcart[29] showed the important fact that the administration of carbohydrates to a fasting man stops the excretion of creatin and that, where carbohydrates cannot be used, as in diabetes, creatin appears in the urine.[30]

The explanation that the result is due to the presence of diacetic acid is, as Cathcart and Orr[31] showed, not tenable.

The work of Loewi in 1902, as Lüthje pointed out, showed that while the amino-acid products of pancreatic digestion of proteins when eaten along with carbohydrates bring about an actual retention of nitrogen, when fed with fats alone they fail to do so.

The indications, then, seem very clear that carbohydrates are essential for the synthesis or re-synthesis of the protein molecule and, if creatin is a potential anabolite yielding the necessary guanidin, the presence of carbohydrates is probably essential for its use in this way and in their absence it must be excreted.

This view, as far as it concerns the total nitrogen and muscle, I ventured to formulate as far back as 1887, and I then attempted to represent it diagrammatically.[32]

The adoption of this view does not invalidate the idea that the formation of creatin is primarily to de-toxicate an excess of free guanidin. The same thing is seen in the behaviour of lecithin, which is manifestly an anabolite, but which seems to have the power of rendering the toxic cholin innocuous.

The Relationship of Creatin and Creatinin.

The importance of the lengthy and voluminous discussion on the relationship of creatinin to creatin seems to me to have acquired an exaggerated importance.

In the bird the creatin in the urine represents the ordinary overflow of the creatin from muscle which is not used for reconstruction. In mammals this is represented by creatinin, but when the disintegrative changes are increased or the anabolic processes interfered with, then creatin appears along with creatinin.

The non-conversion, or only small conversion of creatin injected or taken by the mouth, to creatinin, does not appear to be opposed to the view that the latter is formed from the former. The total formation of creatinin in man is only about 1 grm. per diem, one ninetieth of the total creatin in the body. If this small conversion is all the body has daily to provide for, it is not to be expected that the demand for a sudden increased conversion will be met, and hence it is only natural that unconverted creatin should escape if it is administered even in small amounts. The normal occurrence of creatin in the urine of young children seems to indicate that its conversion to creatinin is a function somewhat late in development.

There is some evidence that the power of conversion is different in different individuals. Thus we found that after a pound of beefsteak with about 1·7 grm. of creatin expressed as creatinin, one member of the teaching staff showed a rise of 0·53 grm. of creatinin and 0·2 grm. of creatin, another a rise of 0·49 grm. of creatinin and 0·177 of creatin, while two others showed no rise in the creatinin, one showing an increase of 0·425 grm. and the other of 0·213 grm. in the creatin excreted.

The question may be asked, why should the neutral creatin be converted into the strongly basic creatinin? The relative solubility of the two substances is a possible explanation of this. Creatin is about one-tenth as soluble as creatinin.

Creatin Investigations Old and New.

It is extraordinary how, in spite of the enormous amount of work which has been done upon the subject, our knowledge of the significance of creatin has advanced so little since Meissner's really wonderful investigations in 1868, now so entirely ignored. In spite of the unsatisfactory methods then available, he concluded that in the bird creatin and not creatinin occurs in the urine, that its amount is increased by giving meat or injecting creatin, that it is higher on a protein rich diet such as liver than on a protein poor diet such as grain, and that it is increased in fasting.

From his observations on mammals he concluded that urea and creatinin have different origins, thus anticipating Folin's theory of endogenous and exogenous metabolism, and that, in the study of creatin metabolism, feeding with meat must be avoided. He found that creatinin was excreted in the smallest amounts in animals gaining weight on a protein poor diet.

The work upon creatin metabolism which has been carried on in many laboratories during the past few years has been somewhat fragmentary and difficult to combine into an organic whole, but I believe that it can be so combined and that a more or less reasonable explanation can be given by the recognition of the fact that its significant part is the guanidin nucleus, and that it is in connection with this that its real meaning is to be found, that free guanidin is detoxicated and rendered available for synthesis into muscle substance by the formation of creatin.

Folin's method has made the investigation of creatin a very simple matter, but so far no reliable and rapid method has been devised for the determination of guanidin or methyl-guanidin. Hence our knowledge of the metabolism of these substances is still very defective. Probably it will not be possible greatly to enlarge it until better methods of analyses have been devised.

III. Conclusion.

To look back upon the progress of knowledge of any branch of science, even upon one so limited in range as that of protein metabolism, is like looking back upon the records of ancient voyages of discovery. There are the same dreams of enchanted islands far to the West—the islands of the Hesperides; the same imaginary accounts of their position and of their characters, too often accepted as all sufficing; the same spirit of scepticism driving some bolder spirit to embark in his cockle-shell boat and sail forth on the ocean of discovery, to find if these imaginings have any reality; the same picking up of some small fragments of flotsam and jetsam, hinting that somewhere out there the land is really to be found; the same failure to advance due to the badly equipped ships or to imperfect seamanship; and again the imagination playing round the few observations and reconstructing images as unreal as those which they displace. Again, as the ships' compasses and means of navigation improved, another attempt pressed further and ending in the discovery of land indeed—but of some barren reef simply telling that not there lie the islands sought for, and warning the next explorer that some other course must be laid. Again the study of the records of past failures and the attempt to decide what must be the next line of advance. Then the next voyage is started, the course set south-west instead of north-west, till some fine morning another barren rock is sighted. But now the mariner starboards his helm and off goes the ship on another tack till haply the promised island lies ahead—not *one* island but an archipelago, the exploration of which is to be the work of many followers of the original discoverer.

In the discovery of the true position and general features of the metabolism of the proteins in nutrition Liebig, Voit, Pflüger, Zuntz, and Rubner have been the great pioneers. To us is left the smaller task of exploring and charting the archipelago they discovered, of investigating each separate island and of so making complete the great work of our predecessors. And although the voyages before us may be less arduous than theirs, it is still well before embarking to let our imagination play forward along our course, to consider the difficulties and dangers of the voyage, and to see that our boat is adequately equipped. Much of what I have said to-day must be considered as of this nature.

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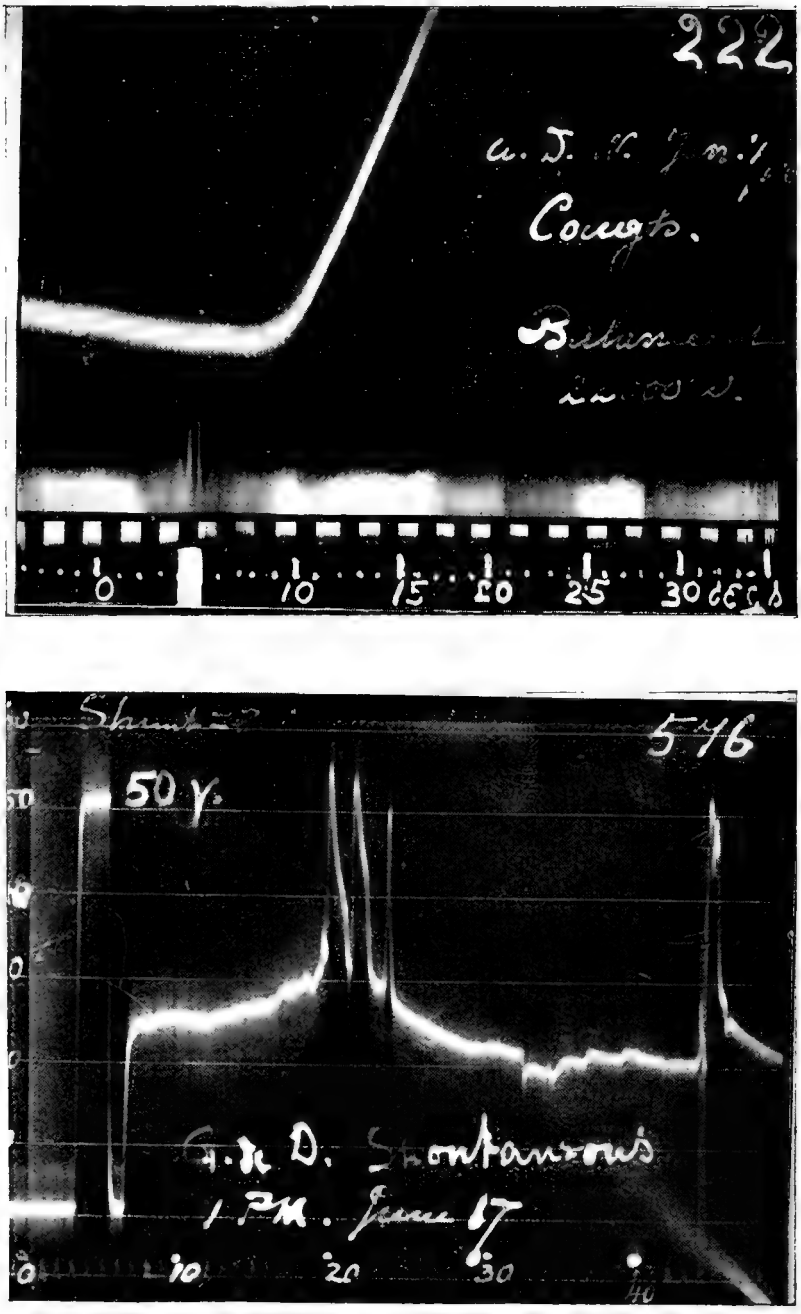

Illustrating Dr. A. D. Waller's Paper 'The Measurement of Emotion.'

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When we are once afloat, let us go forward in the spirit of true discoverers, not obsessed with preconceived ideas of what we are going to find, but with minds open to all that may present itself so that, whatever happens as we go onward, we may add some small trifle to the general store of knowledge.

And what of all those who have sailed forth and suffered shipwreck or returned empty? Are they to be pitied? *No*, if they were of the real stuff, all they asked and what they got was—

'A tall ship and a star to steer her by;
And the wheel's kick and the wind's song and the white sail's shaking,
And a grey mist on the sea's face, and a grey dawn breaking.'

The joy of sailing upon the ocean of discovery—that to the man of science is the real joy of life.

[1] *Biochem. Jour.* 10, 1916, 543.
[2] *J. of Phys.* 52, p. 1, 1918.
[3] *Ztsch. f. phys. Chem.* 41, p. 321; and 42, p. 181, 1904.
[4] *J. of Phys.* 33, p. 106, 1905-06.
[5] *Ztsch. f. phys. Chem.* 81, p. 71, 1912.
[6] *J. of Phys.* 51, p. 347, 1917.
[7] *Biochem. Jour.* 10, p. 263, 1916.
[8] *Ztsch. f. phys. Chem.* 86, p. 435, 1913.
[9] *J. of Biol. Chem.* 24, p. 23, 1916.
[10] *J. of Phys.* 52, p. 1, 1918.
[11] Barger, *Simpler Natural Bases*, p. 79.
[12] *Quart. J. of Exp. Phys.* 10, p. 315, 1916.
[13] *Loc. cit.*
[14] *J. of Biol. Chem.* 3, p. 21, 1907.
[15] *J. of Phys.* 52, p. 70, 1918.
[16] *J. of Phys.* 52, p. 1, 1918.
[17] *Ztsch. f. phys. Chem.* 48, p. 430, 1906.
[18] *Ztsch. f. phys. Chem.* 52, p. 225, 1907.
[19] *J. of Phys.* 51, p. 360, 1917.
[20] *J. of Phys.* 45, p. 115, 1912.
[21] *J. of Biol. Chem.* 10, p. 479, 1911-12.
[22] *Biochem. Jour.* 10, p. 495, 1916.
[23] *J. of Phys.* 39, p. 485, 1910.
[24] *J. of Biol. Chem.* 15, p. 283, 1913.
[25] *J. of Biol. Chem.* 18, p. 195, 1914.
[26] *J. of Biol. Chem.* 17, p. 500, 1914.
[27] *J. of Phys.* 44, p. 43, 1912.
[28] *Ztsch. f. phys. Chem.* 57, p. 476, 1908.
[29] *J. of Phys.* 39, p. 299, 1909.
[30] *J. of Phys.* 41, p. 276, 1910.
[31] *J. of Phys.* 48, Proc. 1914.
[32] *J. of Phys.* 33, p. 1, 1905.

The following Paper was then read [1] :—

The Measurement of Emotion. By A. D. Waller, M.D., F.R.S. (*With Demonstration.*)

[Plate IV.]

Any emotion, spontaneous or provoked, causes nerve impulses through efferent channels to the skin—of the palm of the hand especially—which undergoes a sudden diminution of electrical resistance, which can be demonstrated and measured by galvanometer.

The hand of the subject—as quiescent as possible—is placed in the fourth arm of a Wheatstone bridge. Balance having been established, the subject

[1] For transactions under the Subsection of Psychology, see p. 313.

is stimulated by a real or by an imaginary pin-prick, and a sharp deflection of the galvanometric spot of light is seen about two seconds after the stimulus has occurred.

The magnitude of the response can be measured in ohms, but is more conveniently expressed in terms of reciprocal megohms or 'gemmhos.' A person's hand having an original resistance of, *e.g.*, 50,000 ohms has a conductance of 20 gemmhos indicated by a galvanometric deviation of 20 mm. A painful thought causes an augmented temporary deviation of, say, 5 mm. to 25 mm. or 'gemmhos,' signifying a diminution of resistance of 10,000 ohms.

Any sudden discharge of nerve energy, such as, *e.g.*, a cough or sneeze, is attended by a sudden temporary augmentation of conductivity of the skin of the palm of the hand; this augmentation begins two seconds after the muscular contraction by which the discharge is signalled. The emotive change, as it may be called, varies in magnitude in different persons under similar conditions; in the same person it varies in magnitude with the magnitude of its exciting cause. It varies also in the same person with state of health and time of day. It is most conveniently measured and studied by means of photographic records of the galvanometric spot of light.

WEDNESDAY, SEPTEMBER 10.

1. *Discussion on the Rôle of the Capillaries in the Regulation of the Blood Flow.* Dr. H. H. Dale, *F.R.S.*, Professor W. M. Bayliss, *F.R.S.*, Professor E. H. Starling, *F.R.S.*, Professor A. D. Waller, *F.R.S.*, Professor D. Noël Paton, *F.R.S.*

The following Paper was then read :—

2. *Butter and Margarine. By* Professor W. D. Halliburton, *F.R.S.*

THURSDAY, SEPTEMBER 11.

Joint Meeting with Subsection of Psychology and with Section F, at which the following Papers were read :—

1. *The Influence of the Six-hour Day on Industrial Efficiency and Fatigue. By* H. M. Vernon, *M.D.*[1]

Lord Leverhulme suggests that, instead of the usual eight-hour shift system, in which, as a rule, the machinery is running only forty-four hours a week, the workers should be put on to two six-hour shifts every day, viz., from 7 A.M. to 1.30 P.M., and 1.30 P.M. to 10 P.M., with half-hour breaks for meals. By this means the machinery would be kept running for seventy-two hours per week, and, as the overhead charges for machinery are often higher than the cost of wages, it would still be possible to pay the workers as much for six hours' work as for eight hours' work, even if their rate of production did not improve in consequence of the shorter hours.

The available evidence does not indicate that there would be much improvement of output in many industries. In the tinplate trade the millmen sometimes work eight-hour shifts and sometimes six-hour shifts, and their hourly

[1] See Reports Nos. 1 and 5 of the Industrial Fatigue Research Board, London, 1919 and 1920.

Memo.—No. 18 of the Health of Munition Workers' Committee, London, 1917 (col. 8628).

output was found to be only 10 per cent. greater in the latter instance than in the former. In the iron and steel industry a reduction of shift from twelve to eight hours caused no increase of hourly output from blast furnaces and rolling mills, but 2 to 9 per cent. increase from open-hearth steel furnaces. In the cotton-spinning mills of the United States a reduction of two or three hours in the weekly hours of work caused an almost proportional decrease of output. However, very different results were observed in certain munition industries. Men engaged in the somewhat heavy operation of sizing fuse bodies increased their hourly output 39 per cent. when their nominal hours were reduced from sixty-seven to fifty-six per week, and their actual hours of work from 58.2 per week to 50.6 per week, or their total weekly output went up 21 per cent. Women engaged in turning aluminium fuse bodies on capstan lathes improved their hourly output 56 per cent., and their total weekly output 15 per cent., when their hours of actual work were reduced from 66.0 per week to 48.6 per week. The reason why reduction of hours causes such different effects in different industries is because of the various degrees to which the work is controlled by the personal element, and by machinery. In sizing fuse bodies, the men are not dependent on any machinery whatever, and can speed up to any extent they wish. In turning fuse bodies, the women are to some extent limited by the speed of the machinery. In another operation known as boring top caps, the youths employed fed the caps into semi-automatic machines which could not be speeded up. Consequently their output could only be improved by their keeping more closely to their work, and it was found that when their hours of actual work were reduced from 72.5 per week to 53.1 per week, their hourly output increased only 27 per cent., or was insufficient to balance the reduction of hours, and in consequence their total weekly output fell off 7 per cent.

It is probable that in most industries the eight-hour day does not cause more than a moderate amount of physical fatigue. The workers suffer rather from monotony and boredom, as many of them are engaged on the same task day after day and year after year. Especially on these grounds it is to be hoped that some such scheme as Lord Leverhulme's will gradually be adopted in the industrial world, but it cannot come suddenly, as it might render us unable to compete in the open markets of the world with other countries which adopted, for instance, two seven-and-a-half-hour shifts per day, instead of two six-hour shifts.

Lord Leverhulme suggests that, in addition to six hours' factory labour, the workers should spend two hours daily in educational and physical training. There is much to be said for this plan.

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2. *Physiological Fatigue and Village Meeting Halls.*

By Miss C. Smith-Rossie, *Diplomate Royal Sanitary Institute.*

Educational fatigue is always coincident with nerve exhaustion. This is one reason why Adult Evening Continuation Schools have not much success. To make them successful the surroundings where they are held must be as tonic as possible. In British villages this is difficult—hence reconstruction of the British countryside is delayed. The best nerve tonic is to make the student really desire to learn.

In Denmark after her disastrous war in 1848 things were everywhere on the point of ruin—thriftlessness, drink, and an apathetic peasantry were sending the country drifting, Continuation Schools had no chance of success, the students were always 'too tired' to learn. They had their eyes blind by ignorance of cause and effect like the present state of Russia. Bolshevism might have been the end. But a small band of men under Bishop Grundvig undertook the task of popularising countryside education and spreading the nerve tonic against educational fatigue. In an abstract like this it is impossible to describe their *modus operandi*, but in order to make their work permanent almost every Danish village to-day has its own meeting hall built on popular lines for the stimulation of Adult Evening Continuation Schools—schools not run on dry and hard lines, but adapted to give tonic stimulation to the hard-worked students. And the

plans of the Continuation Classes are run in the same way. Not merely subjects of trade or industrial progress being introduced, but so as to help forwards the slow *imagination* of the country dwellers and by *variety* prevent that weariness of learning which always falls on those who have worked hard and been meagrely fed all their lives. Thus the system in Denmark contributes a factor towards the solution of educational fatigue—viz. nerve stimulation.

Another factor of educational fatigue is any strained position of sitting, especially in the case of working men and women whose muscles are not elastic. The meeting halls of the Danish villages provide against this by the adaptation of their chairs to adult needs. I shall not say anything as regards the advantages of full ventilation or freedom from the noxious fumes of carbon dioxide due to unhygienic stoves, for this is well known to be a great cause of educational fatigue so far as physiology is concerned, but I may add that I have known of very good village schools inspected by the authorities of England and passed as satisfactory which were far from sanitary in these matters. The fact is educational fatigue is passing all over our country except for money-making projects, and this is the cause of mental slowness and want of foresight in many classes. We all need the tonic stimulant of imaginations made vivid by fuller courses of study, and this can never be achieved in villages unless the Danish meeting halls with their steps upwards to the peasant—Universities and broader views of education—are encouraged amongst us.

To reconstruct England these halls are needed unless all the great scheme of the new Education Acts is not to be thrown away so far as the countryside is concerned.

Measurement of the Energy Output of 'Heavy Workers' (Dock Labourers). By A. D. Waller, *M.D., F.R.S. (With Demonstration).*

The most convenient and expeditious method of measuring the output of mechanical energy taking place in the course of muscular work is to take observations at convenient intervals of the rate at which CO_2 is expired—*i.e.*, to take a record of successive CO_2 ordinates (c.c.'s CO_2 per sec. for periods of 30 ± 2 secs.) during the working day.

B. *Piece-Work.*

T.K. Monday, Dec. 16, 1918.					
Time	Time	Litres	c.c. exp. air per sec.	% CO_2	c.c. CO_2 per sec.
8.0 a.m.	60	21	350	2·2	7·70
9.0	30	20	666	2·0	13·32
10.0	30	21	700	2·3	16·10
11.0	30	23	766	2·5	19·15
11.45	30	21	700	3·0	21·0
1.0 p.m.	60	20	333	2·5	8·32
2.0	30	19	633	4·0	25·32
3.0	30	21	700	4·4	30·0
4.0	30	24	800	4·5	36·0

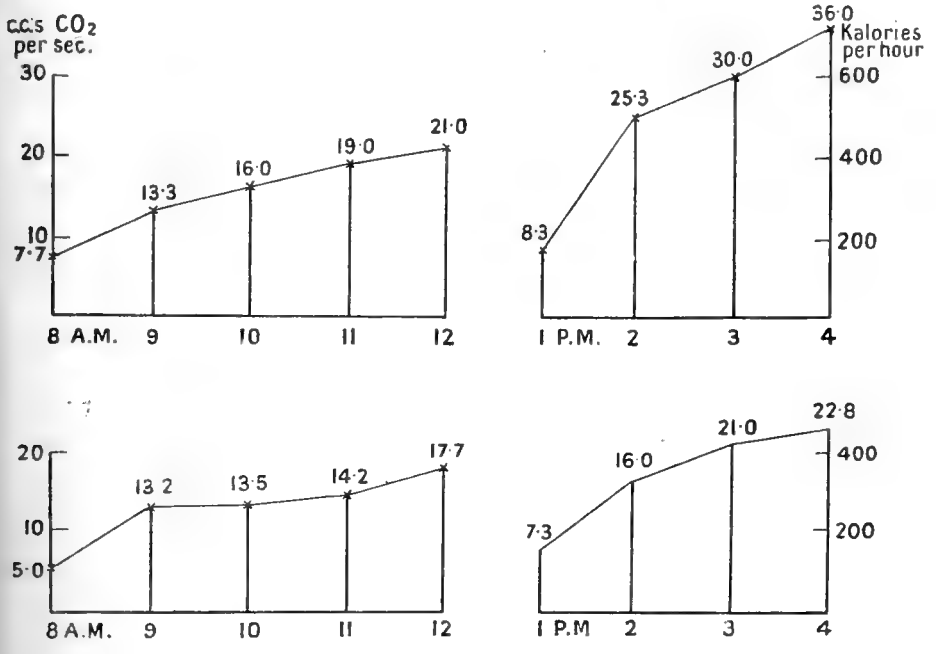
A. *Time-Work.*

T.K. Wednesday, Dec. 18, 1918.					
Time	Time	Litres	c.c. exp. air per sec.	% CO_2	c.c. CO_2 per sec.
8.0 a.m.	60	15	250	2·0	5·0
9.0	30	18	600	2·2	13·2
10.0	30	15	500	2·7	13·5
11.0	30	17	566	2·5	14·1
11.45	30	19	633	2·8	17·7
1.0 p.m.	60	20	333	2·2	7·32
2.0	30	15	500	3·2	16·0
3.0	30	18	600	3·5	21·0
3·45	30	18	600	3·8	22·0

The above are typical records taken upon a 'heavy worker' at the East Surrey Docks by courtesy of the Port of London Authority—A of an average day's work (laying of a concrete pavement) by a first-rate labourer on time pay; B of an extra heavy day's work by the same labourer (coaling) on piece-work pay, of which the conditions are such as to secure maximum

physiological effort and maximum mechanical output. (The piece-work system in force at the East Surrey Docks is as follows : A voluntary association of labourers or ' gang ' of, say, six men contracts to shift 100 tons of coal at so much per ton within *n* hours. The gang earns money in common; each member works under observation of his mates, and works hard; there can be no slacking.) What may be termed the calibration of a labourer is completed when the hourly ordinates of his CO_2 exhalation per second have been taken for the whole day (or for several days).

These ordinates can thereafter (or directly) be translated into calories per hour by multiplying the caloric value of 1 c.c. CO_2 × 3,600, or assuming an average caloric value of 1 c.c. CO_2 = at an average value of the Respiratory



Quotient = 0·90, the conversion can be made into kilo calories per hour by taking the factor × 20 for the CO_2 ordinate—*i.e.*, 1 c.c. CO_2 per sec. = 20 calories per hour.

Averaging from the last three hours of two days for the labourer T.K. I obtain (in rounded figures) :

For time work, 21 c.c. CO_2 per sec., 420 kilo calories per hour.
For piece work, 14 c.c. CO_2 per sec., 280 kilo calories per hour.

Otherwise expressed, the physiological cost of his labour to T.K. is

$$\frac{\text{on time work}}{\text{on piece work}} = \frac{2}{3}.$$

Due precautions against observational error must of course be taken; these do not, however, render the method at all cumbersome; the interruption of work is minimal and not objected to by men while working on the gang system, when each minute's work by each member means money to all members.

The method is best described by an actual demonstration of the determination of the resting value of the CO_2 ordinate of any one of this audience.

The demonstration will be completed in three minutes, which I will fill in by placing on the board the figures obtained in an analogous observation made this morning upon my daughter to ascertain in her case the physiological cost

of swimming. Two readings were taken: A, immediately after swimming 100 yards to the landing stage at the Bournemouth pier-head at a moderate speed—*viz.*, in 150 seconds; B immediately after swimming 20 yards to the landing stage, pulling my inert body in accordance with life-saving drill. The following are the results:

—	Time of Collection of expired Air	Ventilation		CO_2 (gross)	
		Litres	c.c.s per sec.	Per cent.	c.c.s per sec.
100 yards (at 2 feet per sec.) .	30 secs.	19	633	3·3	20
20 yards (life-saving) . .	20 secs.	18	900	2·9	26

Resting CO_2 = 3 c.c. per sec.
∴ Net CO_2 for normal swimming = 17 c.c. per sec.
,, in life-saving drill = 23 ,, ,,

It is nothing more than a pure coincidence that these values have come out very nearly in the relation for time work and piece work in the case of the labourer T.K.

A second trial carried out on the next day at rather higher speed gave rather higher figures, but in the same ratio—2 for simple swimming as compared with 3 for a life-saving swimming effort.

Bag	Time	Ventilation Litres	—	Per cent. CO_2	CO_2 per sec.
7	25	21·8	872	3·0	26·16
8	20	19·9	995	3·4	33·3

Resting CO_2 = 3 c.c. per sec.
Net CO_2 for swimming = 23 per sec.
,, ,, life-saving = 30 ,,
Time of 100 yards = 145 secs.
,, 20 yards (life-saving) = 35 secs.

Objection has been raised to this method of work calibration to the effect that the calorific exchange value of CO_2 fluctuates with fluctuations of the Respiratory Quotient CO_2/O_2. As a matter of fact this value is rather higher than normal during prolonged work, and does not sensibly fluctuate. If it did fluctuate, it could do so only within the following limits:

Equivalence of 1 c.c. CO_2 at R.Q. from 1·00 to 0·70.

R.Q.	Calories	Kilogrammetres	Calories per hour
1·00	5·047	2·155	18·17
0·95	5·317	2·270	19·14
0·90	5·587	2·386	20·11
0·85	5·856	2·501	21·08
0·80	6·126	2·615	22·06
0·75	6·396	2·731	23·02
0·70	6·667	2·846	24·01

The factor × 20 used above for the conversion of c.c.'s CO_2 per second into calories per hour postulates a CO_2/O_2 quotient = 0·91. The calibration of a labourer is essentially complete when his CO_2 ordinate has been recorded. The CO_2 per second datum is converted into calories per hour per individual by

the factor × 20. This figure per individual can be further converted into calories per unit of weight or per unit of surface for the comparison of different individuals. Thus, *e.g.*, in the case of the labourer T.K. weighing 87 kilos with a body-surface = 2 square metres, his energy emission per kilo body weight is for time work $\frac{420}{87}$ or per square metre of body surface $= \frac{420}{2}$.

Mr. P. Sargant Florence, Prof. E. L. Collis, and Sir Hugh Bell also took part.

The following papers were then read :—

4. *The Effect of Heat on the Antiscorbutic Principle in expressed Juices of Fruits and Vegetables.* *By* Dr. E. M. Delf.[1]

5 *The Effect of Preservatives on the Antiscorbutic Substance of Lemon Juice.* *By* Miss A. J. Davey.

6. *The Pathology of Pellagra.* *By* Dr. H. E. Roaf.[2]

7. *Measurements of Heat Loss and of Sun Radiation in Egypt and in Palestine.* *By* Dr. H. E. Roaf.[3]

SUB-SECTION OF PSYCHOLOGY.

TUESDAY, SEPTEMBER 9.

Address by the Chairman, Dr. W. H. R. Rivers, *F.R.S.*, *on Psychology and the War.*

The following Paper was then read :—

The Theoretical Interest of Industrial Psychology.
By Professor T. H. Pear.[4]

WEDNESDAY, SEPTEMBER 10.

The following Papers were read :—

1. *Industrial Overstrain and Unrest.* *By* Dr. C. S. Myers.[5]

[1] A reference to the work dealt with in this paper is expected to be published in *The Lancet.*

[2] To be published in *Journ. Roy. Army Medical Corps.*

[3] See Leonard Hill, F.R.S., *The Science of Ventilation and Open-Air Treatment*, published by the Medical Research Board.

[4] See *Business Organisation and Management*, Nov., 1919; also *The Application of Psychology to Industry*, Manchester University Press, 1919, and 'Social Psychology and the Industrial System' in *Engineering and Industrial Management*, Sept. 25, 1919, by the author.

[5] See *Ways and Means*, Vol. ii., No. 28, pp. 249-251.

2. *Some Experiments on the Reproduction of Folk Stories.* By F. BARTLETT.

THURSDAY, SEPTEMBER 11.

Joint Meeting with the Section and with Section F.—See above, p. 308.

FRIDAY, SEPTEMBER 12.

The following Papers were read :—

1. *Hypnotism and Mental Analysis.* By Dr. W. BROWN.[1]

2. *Some Suggestions for a General Institute of Applied Psychology.* By THURKILL COOKE.

This paper sets forth the *raison d'être* and first elements of the scheme for the foundation of a General Institute.

Such an Institute has been long felt to be an urgent national need, and, moreover, has been recently rendered imperative, in view of the increase of psychological cases, both military and civil. These cases make their influence apparent in every sphere of life, and contribute in no small measure to that general restlessness and dislocation of the social order which is the natural reaction of war.

Objects.

According to the scheme, the objects of the required centre are :—

1. Psycho-physical Research.
2. The Application of Psychological Method to the Needs of Life.

In pursuance of this two-fold aim, it is proposed at first to devote attention to those departments in which the demand for reconstruction is most urgent, *e.g.* education, law, medicine, and industry.

1. With regard to research, it is evident that any far-reaching change which may be desired—as, for instance, in the educational or the penal system—must depend not merely upon the general progress, but upon a special organisation of science.

2. With regard to the application of method, here it is that, given a well-equipped centre, immediate work may be done. To meet the situation, it is essential that the initial work should be, in the main, diagnostic and educative.

Foundation Principle.

The proposed centre is a General Institute. It will be *general* both in respect of its scientific method and, with the regulation specified hereunder, in respect of the material with which it will deal.

This feature is the basic principle of the scheme, and among the reasons for its adoption are :—

1. It is both the scientific and the practical requirement,

Scientific, because it is in accordance with the historic development of psychology, which is the product, not of one science, but of a number of sciences;

Practical, because all psychological data are more or less allied; the lines of demarcation are not always, at first sight, distinct; and, in practice, no

[1] See 'Treatment of Shell Shock in an Advanced Neurological Centre,' *Lancet*, Aug., 1918; 'War Neurosis,' *Lancet*, April, 1919; 'Hypnotism, Suggestion, and Dissociation,' *British Medical Journal*, June, 1919.

useful end is served by trying to force them apart by artificial or arbitrary distinctions.

2. Experience has shown (as in France, for example) that if any centre of the kind, viz. an institute of applied psychology, is to prove a success, it must be established upon a basis as broad and comprehensive as can be obtained, pandering to no isolated interest, whether scientific cult or professional clique.

Constitution.

Briefly, and in substance, the proposals are :—

That this organisation shall comprise both an Institute and a Society;

That the Institute shall consist of a number of laboratories, representing the several branches of psycho-physical science, and of a number of sections, representing the several departments of life to which that science will be applied;

That the Society, consisting of President, Council, and Members, shall interest itself generally in the scientific work of the centre, and shall constitute the nexus between that centre and the external spheres which furnish its material;

That the Council of the Society shall act in the capacity of an Advisory Committee to the Executive Committee of the Institute; and,

As a preliminary step in the organisation of the scheme;

That those persons shall be eligible, as members of the Advisory Committee, who are duly qualified specialists in mental science, or some technical branch thereof, or who are authorities in one of those departments to which psychological method requires to be applied.

Regulation.

As only a fraction of the resources of modern psychology are as yet applied, the prospective field of application is wide. In devoting attention to that field, however, the General Institute will not undertake any form or quality of work which may be, with more propriety, undertaken at a separate centre, or which does not wholly accord with its fundamental scientific aims. But, with this proviso, it will endeavour to give assistance wherever sought with the sanction of proper authority, and, in the solution of all practical problems, will invite the harmonious co-operation of each department which its work may concern.

Joint Meeting with Section H.—See Section H, p. 292.

Section K.—BOTANY.

President of the Section: Sir Daniel Morris, K.C.M.G., M.A., D.Sc., D.C.L., LL.D.

TUESDAY, SEPTEMBER 9.

The President delivered the following Address :—

It was with a feeling of great responsibility that I accepted the invitation to preside at the meeting of the Botanical Section of the British Association and to follow in the footsteps of the distinguished men who have occupied this position, and especially at this time when the circumstances of the country and the Empire call so largely for the co-operation of all interested in botanical research and the application of science to reconstruction after the war. It is well to bear in mind that while the justification of science depends upon its general application to the affairs of life, we must not forget that the first conditions of its assured progress is the recognition of the patient and exhaustive investigations of the laws of Nature which are immutable. The consolation is that what we wrest from Nature holds good for all time.

During the great war which has now happily been brought to a close it has been made abundantly clear that in Botany, as in other applied sciences, we must rely in future less on chance individual effort and initiative. We must co-operate our efforts and organise them at every stage, bearing in mind that we shall always require the services of the worker in pure science to solve those larger problems of national importance which confront us. We must be armed by science, or we shall be placed at a great disadvantage in the great struggle now before us. We are told that it is absolutely necessary for the prosperity and safety of the country that the development of the resources of the Empire and the production of our industries must be on a scale greatly in excess of anything we have hitherto achieved. As an Imperial people it is our duty to develop our resources to the fullest extent.

Fortunately, a great change is taking place in the attitude of the Government and the State towards Science, and it is noticeable also in the relations of Science to industry and commerce.

Since we last met we have lost a number of devoted workers in Botany. Professor Daniel Oliver was the highly esteemed and valued coadjutor of both the Hookers, and his conscientious devotion to duty and unrivalled knowledge of flowering plants raised him to a distinguished position among botanists of all countries.

Another Kew man, George Edward Massee, the well-known mycologist and plant pathologist, has left an enduring mark on British mycology.

Clement Reid occupied a unique position in relation to geology and botany. His book on 'The Origin of the British Flora' was an important addition to botanical literature. Jointly with Mrs. Reid he produced a quarto monograph of the Pliocene Flora. Ethel Sargent, the President of this Section in 1913, was one of the most gifted and distinguished workers in Botany. She was the first woman to serve on the Council of the Linnean Society. Her name will long be associated with the well-supported and well-reasoned theory of the origin of Monocotyledons.

In the early part of last year another gap in the ranks of women botanists

occurred in the death of Dr. Ethel de Fraine. She investigated the seedling structure of the Cactaceæ and the rare fossil stem *Sutcliffia*. She was also deeply interested in ecological work, and correlated the structural features of plants with morphological and ecological problems.

Professor Pearson, the founder of the National Botanic Garden at the Cape, accomplished much valuable work in a short life. He was an exceptionally good explorer, and his contributions to botany ranged over a wide field. His important investigation of *Welwitschia* enabled him to amplify and extend Sir Joseph Hooker's classic memoir on that genus. He also threw much new light on the Gnëtales.

In the death of Philippe de Vilmorin the cause of science and genetics has lost a good friend. He was the grandson of Louis de Vilmorin, one of the first who had inklings of the work of heredity, and rendered great service in the improvement of the sugar beet.

Mr. F. Ducane Godman, in his great work 'Biologia Centrali-Americana, comprising sixty-three large quarto volumes, for which he bore the whole expense, has an enduring monument of his learning and generosity. He belonged to the small but distinguished class of Naturalists who devote their time and resources to promote research from pure love of Science.

Sir Edward Fry's life-long interest in British Botany ranged in later years over the wide field of cryptogamy. He is said to have 'wished, at times, that men of science could be induced to state and argue the debatable matters with all due forms and production of evidence as matters of fact are debated in a court of law.'

Apart from those who have passed away in what may be called the course of nature, a sad aspect of the losses sustained in the great war is the death of so many brave young men for whom it was anticipated that a bright and successful career was open in the domain of Science. Their names are inscribed on the Roll of Honour, and we gratefully bear them in memory. I ask you to stand for a moment to renew our fellowship with the immortal dead.

From the point of view of the scientific exploration of the resources of the Empire it is satisfactory to note that the publications dealing with the floras of tropical and sub-tropical countries have been continued. These involving, as they do, so much labour and forethought are of more than passing interest from the fact that they serve to reveal the distribution of plants that may eventually prove of great economic value. A close investigation of tropical plants is necessary, as allied species or varieties of one and the same species sometimes differ greatly as regards their economic value. An instance of this kind has been observed in the case of the so-called 'bastard logwood' of Jamaica. The botanical characters of this are almost identical with those of the common logwood, but its physiological properties are so different that it is worthless for commercial purposes. A parallel case is furnished by *Robinia pseudo-acacia*, the wood of which is described by Sargent as being reddish, greenish-yellow or white according to the locality, but the yellow and white varieties occur side by side in at least one locality. The carefully prepared 'Flora Capensis,' of which eight volumes have been issued under the auspices of Kew, is now nearing completion. In this connection it is interesting to learn that the Government of the Union of South Africa has recently appointed an Advisory Committee for a systematic survey of the characteristic botany of that portion of the Empire. Another very important contribution to systematic botany is the 'Flora of Tropical Africa.' Of this six volumes have been published. The grasses, which will occupy the ninth and last volume, comprise a description of 400 species, or a little over one-third of the grass flora of tropical Africa.

In the Western Tropics the 'Flora of Jamaica,' containing a systematic account, with illustrations, of the flowering plants of that interesting island and published by the Trustees of the British Museum, is making good progress. A 'Flora of Bermuda,' with all genera illustrated by text figures, as in the 'Flora of Jamaica,' was issued last year by Dr. N. L. Britton, of the New York Botanical Gardens. About 8·7 per cent. of the total native flora of 709 species is regarded as endemic.

To supplement Hooker's great 'Flora of British India' the second part of Gamble's 'Flora of Madras' appeared last year. Duthie's 'Flora of the Gangetic Plain" is still in hand. Of Maiden's comprehensive monograph 'A

Critical Revision of the Genus Eucalyptus.' thirty-five parts, comprising 181 species, have, so far, been issued.

Digressing for the moment, I would mention that British Guiana, with an area equal to that of Great Britain, on the mainland of South America, is full of interest, but its rich and abundant flora, extending from an extensive coast line to the high lands of the interior, with the Kaieteur falls and the remarkable Roraima Mountain rising to over 8,000 feet, is little known to the world at large. There is, also, the fertile and easily accessible island of Trinidad, at the mouth of the Orinoco, which has been a British Colony for more than a hundred years. Although the necessary material is conveniently at hand in the local herbaria, brought together with great care during the last thirty years, neither of these portions of the Empire has, as yet, published a handy working flora from which their special botanical and economical resources might be ascertained. In these days a systematic exploration of our tropical possessions and the publication of the results in an accessible form should serve as the first step in their fuller development.

Of interest from another point of view is a new supplement of 'Index Kewensis' now ready for the press. This invaluable work of reference was originally prepared at the urgent request of Darwin, who undertook the cost of producing it. The Bentham Trustees have lately issued a complete index to the plates and names of plants that appear in the thirty volumes of 'Hooker's Icones Plantarum.'

Further, it is worthy of note that the Royal Horticultural Society is arranging, with the help of Kew and the British Museum (Natural History), to undertake to bring out a new edition of Pritzel's 'Iconum Botanicorum Index.' The original work, indispensable to a botanical and horticultural library, contained 107,000 entries. It is estimated that, at least, an additional 125,000 references will appear in the new edition.

This may be an appropriate occasion to refer to the new branch of botany which has lately come into prominence as one of the results of the devotion to nature study and the contemplation of the characteristic features of vegetation as we find it distributed over the earth's surface. Ecology is capable of enormously extending the outlook of botany, and it has so largely added to the interest of field work that we may wonder that the phenomenon of vegetation so long displayed before our eyes had not suggested its sociological aspects long ago. Ecology has its Society and Journal, and it bids fair to fully establish itself in the household of botany. It is hoped it will mitigate some of the admitted drawbacks of purely laboratory work and revive the old Natural History spirit of former days. As pointed out by Thiselton-Dyer, it is to this spirit that we owe the Darwinian theory which rested on every point on a copious basis of fact and observation made in field and forest.

In describing the principal forms of plant communities the first requisite is to become familiar with the species and their distribution in relation to their habitat. This neighbourhood is noteworthy for the opportunities it offers for the study of the natural vegetation of calcareous soils, of the heathlands of the Bagshot sands, as well as of an interesting series of aquatic and marsh plants. The presence of many of the Southern elements of the British flora enumerated by Stapf is also of interest. Among these, to mention a few, are *Simethis bicolor*, *Lotus hispida*, *Gladiolus illyricus*, *Ludwigia palustris*, *Lobelia urens*, *Erica ciliaris*, and *Pinguicula lusitanica*.

The phenomenal spread of a comparatively new marsh grass (*Spartina Townsendii*) along certain portions of the South Coast deserves careful study. It is supposed to be a hybrid between *S. stricta* and *S. alternifolia*. It is claimed to be pre-eminent among halophytes on account of the extraordinary vigour with which it spreads over mud flats and eventually forms meadows to be measured by thousands of acres in the neighbourhood of Southampton Water and Poole Harbour. It is a question whether it may not develop into a serious menace to navigable waters. On the other hand, it may prove capable of being utilised in suitable localities as a reclaiming agent. Its economic value in providing material for paper-making or as food for cattle may also receive attention. It is unnecessary to enter into further details, as Professor Oliver, who has kept this grass under observation for many years, has kindly consented to give an address summarising the results.

The critical study of British plants was supposed to be an exhausted field, but with the necessary insight and careful and critical observation there is much work still to be done. Exchange clubs are active, and additions to local floras are continually being made. New species, varieties, and hybrids are published from time to time. As an instance, *Potamogeton upsaliensis*, hitherto only known in Sweden, has recently been found in this neighbourhood. Hybrid orchids are being keenly studied, and the occurrence of hybrids in this and other classes of plants opens a wide and interesting field of investigation.

A much-desired piece of work is a continuance of Starkie Gardner's interesting investigation of the fossil flora of the Bagshot beds so well shown in the Bournemouth and adjoining cliffs. Some of these have proved exceptionally rich in remains of tropical and sub-tropical plants. Among the genera claimed to be represented are *Acacia, Smilax, Lygodium, Gleichenia, Myrica, Eucalyptus, Araucaria, Diospyros, Nipadites, Sequoia*, and a palm (*Iriartea*), now only found in tropical America. So far, in regard to these plant remains, we may say with La Place : ' What we know is but little : what we do not know is immense.'

After an interval unprecedented in the history of the British Association we meet once more under its high authority so that the leaders in science and men of affairs with wide and deep experience may take council together and discuss the latest results of scientific investigations. We have everything to gain from a free exchange of experience and ideas. This is a time when science does well to renew its touch with daily life both for its own sake no less than for the sake of true progress. It is recognised that the enormous advance in the material comfort and the prosperity of our race during the last century has been due to the application of science. Nevertheless, in the newer times which we are now entering upon we shall require all our energy and all available scientific knowledge to win through to success. It is encouraging to realise that since we met at Newcastle in 1916 there has been a truly remarkable progress in every branch of science. Also, a fuller recognition of the value of science and education as means whereby the material interests of the world may be enlarged.

My distinguished predecessor, whose work has been largely concerned with the systematic and philosophical side of Botany, has rightly expressed the general desire for a more cordial understanding between botany and its economic applications. ' It is certain,' he said, ' that our outlook must be widely different after the war, and the changed environment must find us ready to respond in the interest of our country and mankind.'

With your permission, and acting on a suggestion made by my Committee, I propose to travel a little outside the usual scope of previous addresses and review the many efforts that have been made, and are still being made, to promote the interests not only of the home land but of the Empire as a whole. My own activities have been more or less intimately connected with the Tropics. Their productions are daily in increasing demand, and are becoming more and more necessary to the inhabitants of temperate countries. Before the war it was estimated there were about three million square miles of British territory within the tropical zone. A portion of this area, including India, was already producing commodities of the estimated value of 230 million sterling.

It is, therefore, in the national interest to keep closely in touch with the conditions and prospects of our tropical possessions, in order that we may render them still more capable of supplying the raw material so necessary to the maintenance of our commercial prosperity.

In recent times one of the most important steps taken in this connection was the establishment, on the recommendation of a Royal Commission, appointed by Mr. Joseph Chamberlain, of an Imperial Department of Agriculture in the West Indies. The provision for the upkeep of the Department, approved by Parliament, was at the rate of £17,400 per annum. From the first special efforts were made to bring the resources of science to bear on all matters relating to the welfare of the Colonies concerned. The laboratories and the headquarters of the Department were established at Barbados, together with a staff of University men with special qualifications for research. The latter carried on their work in co-operation with officers of a like standing at British Guiana, Trinidad, and Jamaica.

When fully organised the Department made grants for teaching science at

colleges and secondary schools, and for the maintenance of agricultural schools, botanic gardens, and experiment stations. Special attention was devoted to research work in raising new varieties of sugar-canes and other plants, in the investigation of diseases affecting crops, and the general amelioration of the conditions under which they were grown. Further, by means of an efficient staff of travelling agricultural instructors and an abundant supply of literature the Department was brought into intimate touch with all classes of the community. At the end of ten years of strenuous effort it was noticeable, owing to the expansion and improvement of old industries and the introduction of new industries, the general conditions in the West Indies were greatly improved. This may be illustrated by the fact that the public revenue of the Colonies had increased from £2,546,724 in 1894 to £3,914,434 in 1911, while the total trade during the same period had increased from £16,270,474 to £26,949,086. There was thus an increase of 65 per cent. in the total revenue and of 60·5 per cent. in the total trade. In reviewing the situation in the West Indies, as the result of the activities of the Imperial Department of Agriculture, and those associated with it, the late Prime Minister said 'the work of the Department was universally and gratefully acknowledged by the planters to be largely responsible for the improved state of affairs in all branches of agriculture, and he believed—and he spoke with some experience—it would be difficult to find a case in which any analogous experiment made by the Home Government had attained such speedy and satisfactory results.'

A gratifying proof of the value of the work of the Imperial Department of Agriculture in the West Indies was the formation of several departments on similar lines, first at Pusa in India in 1902, and subsequently in all the tropical Colonies in the New and Old World. Further, twenty competent officers trained in the West Indies are now in charge of Departments of Agriculture in Ceylon, Mauritius, Federated Malay States, Fiji, and on the staffs of the Imperial Department of Agriculture in India and the several Colonies in East and West Africa. Another interesting feature of West Indian progress was the wider appreciation of improved methods of cultivation and the value of science by members of the planting community. For instance, in 1898 the aggregate amount voted by the local legislatures for staffs, laboratories, and botanic and experiment stations was at the rate of 14,000*l.* per annum. Apart from the funds of the Imperial Department of Agriculture, it is probable that, directly or indirectly, the total amount contributed locally for scientific services is now not less than 60,000*l.* per annum. It is also to be noted that during approximately the same period the number of scientific and technical officers had increased from 67 to 142. This, however, is not confined to the West Indies, for in a list, published annually at Kew, the number of scientific officers attached to botanical establishments in various parts of the Empire had increased from 122 in 1892 to 332 in 1918.

There can be no doubt that not only in the West Indies but in all parts of the Empire 'enlightenment as to the objects, methods, and conditions of scientific research is proceeding at a rapid rate.' A review of the circumstances relating to all the Overseas Dominions would be a task entirely beyond my province. Perhaps the most interesting feature of the progress made is in connection with the application of the laws of heredity to the improvement of such highly important crops as sugar, wheat, and cotton. The problems associated with these involve both scientific and economic considerations. As regards the scientific side, it is fortunate that with the beginning of the twentieth century came the rediscovery of Mendel's facts and the stimulating energy of the genetic school which has brought us an entirely new point of view in regard to the improvement of field crops.

Great importance is attached to the improvement of the sugar-cane, as the prosperity of many of our possessions depends upon it. Further, the requirements of this country approach something like two million tons per annum. The sugar-cane, although its origin is unknown, has been cultivated in tropical and sub-tropical countries from remote ages. Up to a recent date its propagation was purely vegetative, as it was supposed to have lost the power of producing mature seed. Occasionally by bud variation a new cane was obtained possessing special merit. For instance, at Barbados in 1903 a 'sport' cane cultivated under normal conditions yielded at the rate of 8,070 pounds of sugar per

acre as compared with 6,228 pounds yielded by the original cane. In Java, where the white Cheribon was practically the only kind grown, a red cane suddenly appeared. This was carefully multiplied by cuttings until a large area was planted, with the result that a greater tonnage of canes was raised per acre and the juice was richer.

Sugar-cane seedlings were observed at Barbados in 1858, but it was only in 1888 that Bovell and Harrison were in a position to utilise the discovery and obtain thousands of self-sown seedlings for experiment purposes. Similar seedlings were also available in Java about the same time. As about this period the standard canes in sugar-growing countries were showing signs of being severely attacked by disease the discovery of seedlings was a fortunate circumstance. In fact, in some cases it may be regarded as having probably saved the industry. A careful examination of the floral characters of the best varieties of sugar-canes disclosed the fact that in some cases the ovary was normal while the stamens were infertile. Advantage was taken of this circumstance to secure cross fertilisation by planting selected canes of each type in alternate rows. By this and other means, skilfully devised, several varieties of sugar canes of great merit were raised.

The possibility of breeding sugar-canes by cross fertilisation under control on Mendelian lines has so far not proved practicable. Partly on account of the enormous number of florets in the panicles and their microscopic character, but chiefly owing to the difficulty of manipulation in the field. Lewton Brain and Stockdale made careful experiments in 1903 and 1905, but the results in both cases were disappointing. In spite of this a large number of seedling canes have been raised in cases where the seed-bearing parent only was known. In others neither parent was known. The results, on the whole, have not been unsatisfactory. Seedling canes in many cases have taken the place of the older varieties, while larger returns per acre have been obtained. Further, owing to careful selection there has been a marked diminution in the losses from the attacks of insect and fungoid pests.

In British Guiana it is reported that in the crop of 1918 seedling canes occupied 83 per cent. of the total areas under canes. Similar results have been obtained at Barbados, where Bovell has continued since 1888 in raising canes of great merit. Also in the Leeward Islands, and more or less in Trinidad and Jamaica. The best of the West Indian seedlings have been widely distributed to other countries. The general policy adopted by Harrison in British Guiana as the result of over thirty years' experience in cane selection is briefly summarised as follows : 'We raise as many seedlings as we can from varieties of proved vegetative vigour, and select from those having both well-marked vegetative vigour and relatively high saccharine content.' He adds : 'The characteristics of seedling canes are not fixed, and in many instances characteristics which in the earlier years promised to make a cane of high quality, both in the factory and field, were the first to fail.' Harrison's experience suggests a special line of research, viz., to ascertain the cause of the increase in vegetative vigour and yield that follows a first cross, only to disappear in later stages.

In India there is probably a larger area under sugar-cane than in any other country. Its production of sugar is over two million tons. The larger proportion of this consists of a low-grade quality known as jaggery or *gur*. Palm-sugar is also produced to the extent of half-a-million tons. The sugar-producing areas in India consist of two main portions : A southern portion in Madras, Mysore, and Bombay wholly within the Tropics, and a northern portion outside the Tropics extending from Assam to the Punjab, a distance of one thousand miles. The difference in soil and atmospheric conditions has a marked influence on the character of the canes grown in the two regions. In Southern India the canes are stout and usually as productive in the irrigated areas as in other tropical countries; but in the North the canes are more slender, grow in thick clumps, and owing to the high percentage of fibre are much less productive in sugar.

Speaking generally, the sugar industry in India is not in a satisfactory condition. In spite of the enormous area under cultivation India is obliged to increase its considerable imports of sugar from Java and other countries. To obviate this urgent steps are being taken to improve the character of the canes and establish varieties adapted to local conditions and the circumstances of the sugar growers. The latter are almost entirely of the peasant class or rayats. At

first it was sought to introduce better varieties of canes from other countries. A sugar station was established for this purpose at Samalkola. It was soon evident that the luxuriant canes of the Tropics were not suited to the special conditions existing in Northern India. What was needed was a more hardy type of cane capable of holding its own under the field conditions and the resources of the cultivators. To obtain these they had to be produced in India. With this object in view a cane-breeding Research Station was established in 1910 at Coimbatore, with Barber, an experienced scientific man, in charge. The locality was regarded as favourable because canes were known to flower there comparatively freely. At first the improvement of local canes by selection and later by seedlings from parents of known vigour and high saccharine quality received attention.

In raising seedling canes the chief difficulty was the irregular flowering of the best canes. Barber arrived at the conclusion that until some control of the flowering is obtained work on Mendelian lines was not practicable. In spite of this a large number of selected seedlings are now being raised at the rate of 4,000 per annum. Some of these, lately distributed to the experiment stations in Northern India, have been reported upon as 'entirely satisfactory.'

Much more still remains to be done, but there is reasonable hope that a race of superior hybrid seedlings will be produced that will eventually displace the inferior local varieties hitherto cultivated. To ensure even moderate success in this direction it is recognised that the work of cane-breeding must never slacken, and further, that the means of distribution and the number of stations and capable workers must be increased.

In the considerable literature of sugar-cane breeding in India Barber has brought together a vast amount of information of singular interest and value. In the few years that have elapsed since he has been in charge of the Coimbatore Research Station he has laid the foundation of lines of inquiry that cannot fail to prove of great value in the permanent improvement of the sugar industry in India. It is a good augury as regards the future that the Government of India has lately formed an Imperial Sugar Bureau, whose duty it is to collect and collate the scattered results obtained in various directions and keep closely in touch with the sugar work done in India and in other sugar-producing countries.

In his Presidential address in 1898 Sir William Crookes stated that the prime factor in wheat production was a sufficient supply of nitrogen. As the supply was then showing signs of exhaustion he warned wheat growers of the peril awaiting them. Sir R. H. Rew has now shown that, thanks to the chemist, who came to the rescue, there is practically no limit to the resources of nitrogen. What he hoped for was that the future would see not only a larger acreage in this country under wheat but also a substantial increase in the average yield. During the great war the British people have realised under the stress of a fight for existence that the question of food supply is the most vital of all national interests. Both in this country and in India and in the Overseas Dominions great progress is being made in raising new varieties of wheat yielding large returns per acre and possessing excellent milling and baking qualities. In the pre-Mendelian days excellent work was done in wheat breeding by Saunders in Canada and Farrer in New South Wales. Their work proved of enormous benefit, as it not only provided varieties of superb quality, but also those that could be successfully grown in districts where wheat growing for various reasons was previously impossible. During recent years Biffen by his successful investigations on Mendelian lines at the Plant Breeding Institute at Cambridge has shown that the characteristics distinguishing the numerous wheats can be traced, and the building up of a fresh combination of these characters was possible on practical lines. As the losses caused by disease were so serious, sometimes running to millions of quarters annually, Biffen devoted special attention to the possibility of breeding rust-resisting varieties. He found that the power of resisting the attacks of yellow rust, for instance, was an inheritable character. By crossing 'Gurka,' a Russian disease-resisting wheat, with Square Head's Master, one of the most widely cultivated wheats in this country, Biffen eventually produced 'Little Joss,' which, after trials extending over a period of several years, is said to yield four bushels per acre more than any other variety. Further, it possesses distinct disease-resisting qualities.

Another of Biffen's new wheats is 'Yeoman.' This was raised in order to produce what are known as strong wheats. These are in great demand in this country, as they produce a flour which is much superior for baking purposes to the flour of English wheat. In pre-war days Canadian strong wheats commanded in the market 5*s*. more per quarter than the best English wheat. 'Yeoman' not only possesses the superior quality of Canadian wheat but combines with it the high-yielding character of certain English wheats.

A well authenticated report, supplemented with full details, of the value of 'Yeoman' as a field crop was lately published.[1] It was cultivated under normal conditions, but without artificial manure, on three fields on a large farm near Wye, Kent. The cropped area was a little over twenty-seven acres. The total yield was 2,072 bushels, or an average of about seventy-seven bushels per acre. One field, previously under beet, comprising three acres two rods and eight poles, yielded 340 bushels, or an average of eighty-six bushels per acre. These results may be compared with thirty-two bushels, the average yield of wheat in this country.

Further, in another variety known as 'Fenman,' Biffen has produced a wheat with a short, stiff straw for the Fen country. This is able to withstand the usual tendency of the ordinary sorts to grow tall and be beaten down and injured in rainy seasons. A most desirable improvement in wheat growing in this country is to obtain a spring wheat combining early maturity with a yield approaching that of winter wheat. There is likely to be a difficulty in securing these most desirable results, but what Biffen has already achieved in dealing with qualitative and quantitative characters offers fair promise of success. The establishment of a National Institute of Agricultural Botany for the further development of plant breeding and the distribution of pure seed may be regarded as essential to the welfare and safety of the nation.

Wheat growing is a very important industry in India. It was estimated in 1906-7 that twenty-nine million acres were under cultivation in wheat with a yield of nearly nine million tons. Of this 90 per cent. was consumed in India. A botanical survey of the Indian wheats was undertaken by the Economic Botanists at the Imperial Research Institute at Pusa in 1910. In the following years by the application of modern methods of selection and hybridisation high-grain qualities were successfully combined with high-yielding power, rust resistance, and stiff straw, so that wheats were produced which gave upwards of forty-one bushels per acre.

Among the best of the new varieties are Pusa 4 and Pusa 12. Owing to an organised system of distribution of seed it is estimated that the area under Pusa 12 during the last wheat season (1918-19) was about 400,000 acres. The area under Pusa 4 was about 100,000 acres. The increased yield of 25 per cent. over the varieties formerly grown in India as well as one shilling per quarter more on the market, owing to the improved quality of the grain, are factors of great value as regards the future of wheat growing in India. Pusa 4 and 12 are said to possess the added advantage of being able to mature with less water than the ordinary Indian wheats.

The important work carried on at Pusa by Howard and his accomplished wife has followed closely on the methods found so successful at Cambridge. It is interesting to note that in obtaining new kinds by hybridisation between Indian wheats and rust-resisting forms in Northern Europe a difficulty in regard to flowering at different periods was overcome by sending the Indian parents to Cambridge for spring sowing and by carrying out the actual crossing with Biffen's new hybrids in England. From the crosses thus obtained Howard reports that a wide range of wheats has been evolved likely to prove superior to Pusa 4 and Pusa 12.

The admirable work done by Biffen at Cambridge and the Howards in India clearly demonstrates the value of thorough acquaintance with pure Botany as a qualification for grappling with questions of economic importance.

In reviewing the gain to Indian wheat growers the Director of the Agricultural Research Institute has recently stated that in view of the favour with which the new wheats have been received and the cordial co-operation of provincial

[1] *Journ. Bd. Agric.* xxv., 1161.

organisations 'it is a modest estimate to assume that in the course of a very few years the area under Pusa wheats will reach five million acres. This means an increase in the near future in the value of the agricultural produce of India, in one crop only, of 75 lakhs of rupees or five million sterling.' Another crop that has received attention is indigo. In regard to this a new method of growing the seed has been worked out, and the cause of the destructive wilt disease has been traced to the destruction of the fine roots and nodules during the monsoon rains. The remedy in this case is the selection of surface-rooted plants which are now in course being generally grown.

Considerable progress has also been made with rice, the chief cereal food of the people of India. Of this eighty million acres are cultivated. A variety known as 'Indrasail' is being rapidly propagated. The yields of this in 1915-16 were 30 per cent. over the ordinary kinds. In 1918 two hundred tons of pure seed were distributed in Bengal, which contains one of the great rice-producing tracts of the world.

Some wheat breeding has been carried on in the Argentine by Backhouse, formerly attached to the John Innes Institution. The conditions in that great country extending from the Straits of Magellan to the tropic of Capricorn are exceptional in the diversity of soil and climate. The wheat cultivated in such widely scattered areas requires to be carefully adapted to local conditions, and the work must take a long time. Confining attention to the dry districts of the north, Backhouse found an interesting variety in general cultivation known as Barletta, which, though mixed and heterogenous, was uniform in possessing a non-shelling character. Further, during periods of drought it acquired the habit of abandoning tillering and producing only one or two rows of ears. Its chief defect was its liability to be attacked by *Puccinia triticum* (not *P. glumarum*). In some years 20 per cent. of the crop was lost owing to this rust. It was ascertained that European varieties immune to *P. glumarum* were susceptible to the Argentine rust.

A Chinese variety taken out by Backhouse was found to be immune to *P. triticum*. From this eventually was built up a form that combined some of the best qualities of the Barletta with the immunity of the Chinese. Backhouse has since endeavoured to increase the size of the grain, which is small in Barletta, and improve the general yield. The adaptability of the Barletta, as a non-sheller, to the conditions in the Argentine is due to the fact that the harvesting is done there by an Australian machine which cuts off the ears and threshes them at the same time. A non-shelling, or what is also known as a tight-glumed, wheat is therefore essential.

As in wheat, so in cotton, this country is almost entirely dependent on foreign supplies. The uneasiness caused by the excessive dependence of the great Lancashire cotton industry, with exports of the annual value of over a hundred million sterling, on supplies from abroad, and the occasional shortage, have led to general action being taken to encourage the more extensive growth of cotton within the Empire. Next to the United States, which in some years have supplied seven-tenths of our imports, India comes second, but the East Indian cotton is not well suited to the requirements of the English spinner. Egypt, as the third producing country, supplies cotton of great strength and fineness.

The most valuable of all cottons is that known as 'Sea Island' cotton owing to its introduction and successful cultivation on the coastal areas in South Carolina, Georgia, and Florida. With regard to this, it is interesting to learn that in recent years Sea Island cotton has been introduced back again to the West Indies, which was probably its original home.

This was effected by the Imperial Department of Agriculture in the West Indies in 1902, when a pure strain of seed raised from plants immune to wilt disease was obtained in quantity from James Island. This insured that the industry from the first was placed on a firm basis, and with the hearty co-operation of the planters an important West Indian cotton industry was successfully established. For some years the West Indian cotton has obtained a higher price than the corresponding grades of cotton from the Sea Islands themselves. The fine spinners in Lancashire are now practically independent for their supplies of this cotton from the United States. Further, it is not improbable owing to the serious attacks of the Mexican boll weevil on cotton plants in South Carolina and Georgia the West Indies may become the only source of supply of

fine Sea Island cotton. To enable the cotton industry to be established in the West Indies it was necessary from the first to ascertain the best type of cotton to grow in each Island, how to plant and cultivate it, how to protect it from insect and fungus trouble, and how to maintain or improve the quality and quantity of the lint produced. The results so far obtained may be realised from the fact that the value of the exports of Sea Island cotton from the West Indies in recent years has reached a total of two million sterling. The general conditions in the West Indian islands owing to their small size and comparative isolation should enable them to maintain a high purity of cotton. In Egypt and other cotton-growing countries with continuous areas contamination by natural crossing leads to rapid deterioration of pure strains so that a system of continued seed renewal is necessary. Harland, whose services in the West Indies have been provided by a grant from the Imperial Department of Scientific and Industrial Research, has in hand important investigations with the view of placing the work of cotton selection and breeding on scientific lines.

He has shown that the yield of lint per acre depends on a number of factors of a morphological and physiological character. In a general way it may be said that the yield is dependent on the climatic conditions, so an effort is being made to produce varieties which will interact with the environment conditions to the best advantage. Although Harland's work so far is of a preliminary character, he is able to suggest the conclusion that, following certain lines of selection and breeding, and bearing in mind the relative importance of lint index and lint percentage, it is possible to isolate a strain of Sea Island cotton with a weight of lint per boll 31 per cent. greater than that of the ordinary sorts in cultivation.

Considerable losses occur in some seasons from the attacks of insect and fungous pests. In some instance the Internal Boll disease is very destructive. This is due to the puncture of the young bolls by cotton stainers (*Dysdercus*) and green bug (*Nezara*) and the infection of the punctured locks or bolls by certain specific fungi which cause either total loss or the staining of the lint, according to the amount and time of infection.

The green bug is naturaly controlled by egg parasites, but the cotton stainers are subject to little or no control. In St. Vincent highly successful results have followed the systematic cutting out, over the whole island, of two species of trees (Seaside Mahoe and the Silk cotton) on the fruits of which the cotton stainers breed during the period between the cotton crops. The investigation of the Internal Boll disease has entailed wide research, and illustrates the great complexity of problems in tropical plant pathology, as also the need of correlation and the combination of knowledge obtained by simultaneous action from several points of view.

A point of scientific interest is the inheritance of immunity in cotton from the attacks of the Leaf-blister mite (*Eriophyes gossypii*). Harland believes he has obtained this by crossing an immune type of native cotton with a susceptible type of Southern Cross Upland cotton. In the F/3 generation all the plants breed true to immunity.[2] This is important from an economic point of view, for it may lead to the possibility of the production of an immune strain of Sea Island cotton which has hitherto been very badly attacked by the Leaf-blister mite. Another instance of immunity from insect attack is a hybrid of maize (*Zea indentata*) and *Teosinte mexicana*, which is claimed to be totally immune to the attacks of certain aphids.[3]

As already mentioned, India is the second largest producer of cotton. In 1906-7 it was estimated that there were about 20 million acres under cotton, with a production of nearly 5 million bales. It is unfortunate that the quality of East Indian cotton is not high in spite of the considerable efforts made in recent years to improve it.

Cambodia cotton for a time proved successful in Southern India, and has lately been introduced to Madras, but chief attention is directed to the improvement by systematic selection of pure strains adapted to local conditions. In Madras in 1917-18 there were 250,000 acres under new varieties of cotton, yielding increased returns to the rayats of the value of £416,000 per annum. A variety known as 'roseum' was planted in the Central Provinces in 1916-17 on

[2] *West Ind. Bull.* xvii., 162.
[3] *Rev. App. Entom.* Ser. A., vi., 29.

700,000 acres, with the result that the profits to the growers reached a value of nearly one million sterling.

Leake's research work in the United Provinces, carried on for many years, is regarded as probably the most complete yet attempted with cotton in India. A variety known as K.22 has been widely distributed, and the produce in 1916 sold at 31 rupees per maund when local cotton was 25 rupees. Further, the ginning percentage has been raised from 33 to about 40, while the lint is of superior quality.

Leake has also been successful in raising an early flowering form of cotton on Mendelian lines. The new form differed from ordinary cotton cultivated in the United Provinces in that it assumed a sympodial instead of a monopodial habit. It not only yielded cotton of high quality, but it was found by its early flowering habit to suit the special conditions of the United Provinces.

As Egyptian cotton comes next to Sea Island cotton in quality it may be useful to refer to what has been done, or attempted to be done, on scientific lines to safeguard the industry. Its importance may be gathered from the fact that the area under cultivation is between a million and a-half and two million acres. Balls has fully reviewed the scientific and other problems that had to be solved in placing the industry on a satisfactory footing.

In the first place, as in all cotton areas, it had to be realised that it was necessary to produce varieties on pure lines. An attempt to produce crosses between American Upland and Egyptian cotton had to be abandoned. It was then resolved to select strains of individual Egyptian sorts and by the study of heredity on Mendelian lines to raise new varieties of pure strain. It was hoped by these means and by organising an effective system of seed distribution, year by year, to maintain the general purity of the crop. The chief difficulty met with was in respect of the relatively small size of the unit areas and the liability of the pure-strain plants being contaminated by pollen carried by wind or by bees from the neighbouring areas. According to Balls, the high-water mark of Egyptian cotton growing was from 1895 to 1899. Since that time, although the actual area under cotton had been increased by 600,000 acres, the benefit measured in terms of cotton alone was small. It is probable that the attacks of the pink boll worm and other pests may have affected the results, but Balls and his colleagues came to the conclusion ' that the falling off in yield was due to a rise in the level of the sub-soil water, or water table of the country brought about by the extension of the irrigation system during the past decade.' The roots of the cotton plant were thus adversely affected at a critical period of growth. This recalls what Howard discovered, that one of the causes of the wilt disease in indigo in India was the destruction of the fine roots and nodules during heavy monsoon rains. This shows, as suggested by Balls, how small was our real knowledge of the root functions of plants, and in the experiments carried on by him and his colleagues in Egypt they were ' semi-consciously building up a general scientific knowledge of root-function worked out on the cotton plant as our material.'

Balls, while carrying out numerous investigations bearing on the production of pure strains of Egyptian cotton, devised a method of recording crop-development by means of illustrative graphs likely to be adopted not only for cotton but other crops. Incidentally, he proved that the close-planting method on ridges adopted by the native cultivators in Egypt was more advantageous than the wider planting adopted in the United States and other countries. It is a sign of the times that a British Cotton Industry Research Association has recently been formed at Manchester to promote a wide scheme of research in connection with the production of cotton and its utilisation in industry. It will employ a staff of scientific and skilled workers, and maintain scholarships, and eventually a Cotton Research Institute is in contemplation. It also proposes to establish research stations in the cotton-growing portions of the Empire for the investigation of the growth of cotton and the careful and complete study of the scientific problems that may arise.

Probably the most remarkable instance on record of the successful combination of science and enterprise in the Tropics is the establishment of a cacao-growing industry in the Colony of the Gold Coast, West Africa. Thirty years ago no cacao of any kind was produced on the Coast. Owing, however, to the foresight of the then Governor (Sir William Brandford Griffith), who sought

the powerful aid of Kew, cacao growing was started in a small way among the negro peasantry, with eventually extraordinary results. After selecting the locality for the experiments, seeds and plants were obtained through Kew, and a trained man was placed in charge.[4] The first exports in 1891 amounted to a value of £4 only. So rapid was the development of the industry that ten years later the exports reached a value of £43,000. By this time both the people and the Government had begun to realise the possibilities of the situation, and systematic steps were taken to organise under scientific control a staff of travelling agricultural instructors to advise and assist the cultivators in dealing with fungoid and insect pests and improving the quality of the produce. In 1911 the exports had increased nearly fourfold, and reached a total value of £1,613,000, while in 1916 what may possibly be regarded as the maximum exports were of the value of £3,847,720.

It should be borne in mind that this Gold Coast cacao industry, now one of the largest in the world, has been called into being and developed entirely by the agency of unskilled negro labour, and on small plots from one to five or ten acres in extent. The controlling factors were, first, the selection of suitable land for cacao growing; next, the selection and supply of seeds and plants of varieties adapted to local conditions; and, lastly, the tactful advice and assistance of trained Europeans backed by the resources of science.

Coming nearer home, Henry, well known from his association with Elwes in the production of 'The Trees of Great Britain and Ireland,' by historical research and experiment has established the fact that many fast-growing trees in cultivation as the Lucombe Oak, Common Lime, Cricket-Bat Willow, Black Italian Poplar, Huntingdon Elm, etc., are hybrids. It was of high scientific importance to discover the origin of these valuable trees. Further, by artificial pollination Henry has succeeded in raising new hybrids which display the extraordinary vigour characteristic of the first generation cross. Perhaps the most notable, so far, is a new hybrid Poplar (*Populus generosa*), which makes the strongest shoots of all Poplars.

The astonishing vigour of hybrid trees is well illustrated in the case of the Cricket-Bat Willow, a natural cross between *Salix fragilis* and *S. alba*. 'This oftens attains in fourteen or fifteen years, from the planting of sets, fifty to sixty feet in height, with three and a-half to four feet in girth—a size suitable for cleaving into bats.' It is claimed in the case of many hybrid trees 'it is possible to produce much greater bulk of timber in a given time.' The common belief that quickly grown timbers are of inferior quality is said not to hold good in respect of any quality in Ash, Oak, and Walnut. In fact, according to Dawson, 'with Oak, Ash, and Walnut the quicker their growth the better their quality in every way. They are more durable, more elastic, and less difficult to work.[5] It is further claimed that by hybridising it may be possible to produce disease-resisting varieties and varieties carrying with them other desirable characteristics.

Difficulties are met with in hybridising trees in this country owing to the variable climate and the absence of pollen and desirable sorts. To obviate these and provide adequately for the work it should be undertaken on organised lines, as in wheat breeding.

Henry has recently made an elaborate investigation into the history of the London Plane (*Platanus acerifolia*).[6] He has established the fact that this tree, never seen anywhere in the wild state, is intermediate in character between an American and a European species. He claims it has all the peculiarities of a first cross. As usual in hybrids of the first generation, its seeds when sown produce a mixed and varied crop of seedlings, in which are variously combined the characters of the two parents.

Henry's researches show that the London Plane probably originated in the Oxford Botanic Garden about the year 1670, when both the occidental and oriental Planes were established there. The finest and probably the oldest London Plane in Europe is growing in the Palace Garden at Ely. It was planted by Bishop Gunning between 1674 and 1684. The vigour of the London Plane

[4] *Kew Bull.* 1891, 169; 1895, 11.
[5] *Science and the Nation*, 138.
[6] *Proc. Roy. Irish Acady.* XXXV. B.2.10.

is remarkable. It is extensively used for planting in London and other towns in this country, and also in Europe and North America, 'as it has been found to surpass all other trees in its powers of resistance to drought, smoke, and other unfavourable conditions of soil and atmosphere.'

In the Tropics breeding experiments in the case of India-rubber trees are likely to prove of great value. In the meantime, selection of seed from the best trees is being carefully carried out in the hope of increasing the general yield of the plantations. In Java the proportion of alkaloids in the bark of introduced Cinchona trees (yielding quinine) have nearly doubled by careful selection on these lines. In the case of rubber trees, which are known to possess marked individuality in regard to the amount of latex which can be drawn from them, it is suggested that seed for planting should be taken only from trees selected for their high-yielding capacity. In fact, the selection of seed bearers may play an important part in the future development and permanence of the rubber industry. Where good seed is not readily available Lock has suggested that the best trees might be raised from cuttings.

Plant-breeding experiments with India-rubber trees have already been attempted, but they are not likely to be of much value if they are confined to empirical and haphazard lines. It is suggested that they should be carried on at well-staffed and well-equipped stations devoted to breeding and kindred problems. Such stations should be established in each of the main rubber-growing regions. Work of this kind must be lengthy and complex, but it is absolutely essential to ensure the safety of an industry which is estimated to be of the annual value in the Middle East of about fifty millions sterling. The Agricultural Department in Ceylon, which is fully alive to the fundamental importance of selection and breeding India-rubber trees, has already taken some action in the matter. For instance, at the Heneratgoda Gardens there are fifty *Hevea* trees whose individual latex-yield has been recorded for every tapping since June 1908. One tree marked No. 2 has yielded an amount of rubber far in excess of any other tree. In 1912 seeds and stumps taken from this tree have been established on a plot of three acres at the Experiment Station at Peradeniya. When the trees are fit for tapping and the good yielders are determined the others will be cut out and the remainder reserved for seed purposes.

Another investigation in hand is to determine whether the latex-yielding quality of *Hevea* trees can be associated with any definite botanical characters and to what extent such characters are transmittible. Twenty trees of the same age growing in a four-acre block have been selected for differences in leaf and bark characters. These are all tapped on the same system, and the yield of rubber from each tree is recorded separately for each tapping.[7]

The value of these and other experiments of a like nature may be realised when, according to Varnet, quoted by Johnson, the yield of rubber from different trees of *Hevea* growing under similar conditions in the same plantation may vary as regards volume of latex from 4 to 48, and in percentage of weight of dry rubber from 1.286 to 14.164.[8]

Bateson a few years ago expressed the opinion that nowhere is the need for wide views of our problems more evident than in the study of plant diseases. Hitherto, he said, 'this side of agriculture and horticulture, though full of possibilities for the introduction of scientific methods, has been examined only in the crudest and most empirical fashion.'[9] Since then some advance has been made in the morbid physiology of plants, but such work to be carried to a successful and practical issue demands careful experiments carried on continuously by specialists for many years.

Keeble suggests that "the professional mycologist is accustomed to confine his attention too exclusively to the active agent of the disease,' while, on the other hand, 'the professional cultivator gives habitually great weight to the possibility of preserving plants from disease by improving his methods of cultivation. Both are right, yet neither is wholly wise, and there is much room for a race of mycologists who not only discover how to cure plants but know

[7] *Kew Bull.* 1917, 118.
[8] *Jour d'Agric. Tropicale*, 1907.
[9] Address, Section M., 1911.

how to cultivate them.' [10] As we have already seen, Biffen and others have shown that under certain conditions the quality inherent in some varieties to resist disease may be utilised to great advantage. The national importance of such work is impressed upon us by the enormous losses sustained every year by rust in wheat, mould in hops, and the widespread disease of potatoes. One of the most striking instances in recent times was the destruction of the valuable coffee plantations in Ceylon. The industry, an exceptionally valuable one, was wiped out in a comparatively few years by the coffee-leaf disease (*Hemileia vastatrix*). In the light of our present knowledge it is not improbable that this disease may have been checked by seed selection or raising an immune race of plants. Or, more probably, as suggested by Armstrong, by regulating the use of essentially nitrogenous manures, which are known in some cases to intensify the attacks of fungoid pests, and substituting the use of phosphates.

In the Malay States the life history of some of the more prominent diseases of rubber trees has received close attention. *Fomes lignosus*, a root fungus, is local in character, and as its effects quickly appear there is time to take remedial measures before the neighbouring trees are affected. *Ustulina zonata*, causing collar-rot, on the other hand, is slow in action, and therefore all the more dangerous. A third rubber disease, *Fomes pseudo-ferreus*, spreads entirely by the contact of the roots with diseased jungle stumps or roots of other diseased rubber trees. As remedial measures are impossible in this instance a clean-clearing policy is being vigorously advocated, and under scientific advice this may become the rule on all young rubber estates in the East. In this country Salmon, who is undertaking a detailed study of the hop mildew (*Sphærotheca humili*), has obtained seedlings which he states 'have retained immunity after four years' trial in a hop garden under normal conditions of cultivation and manuring.' As the depredation of mildew, commonly known as mould, causes great loss to hop growers, the research work carried on by Salmon is watched with great interest. Progress is necessarily slow, but a hop immune to mould would be a valuable acquisition in hop-growing districts. In the successful treatment of the diseases of plants the field of work in the Empire is realised as practically without limit; but it is one in which advance must be made by the development of pure science, and by men with a broad outlook and fully in touch with the practical as well as the scientific side.

As illustrating the occurrence of an incidental result arising from a purely scientific investigation, mention may be made of the discovery of a remarkably tall strain of flax at the John Innes Institution. This, if capable of being established on pure lines, may prove of economic value. It is a hopeful sign that the appreciation of the work done at this institution, under the stimulating energy of Bateson, is increasing day by day. The broad-minded interpretation that has been placed on the generous bequest made by Mr. Innes and the recognition of the fact that an accurate knowledge of heredity must form the basis of the bulk of the new work in horticultural breeding are full of promise. We have, further, the assurance that recognition will be given to the principle that if progress is to be made theory and practice must be closely interwoven. Amongst other important investigations undertaken at the John Innes Institution, Miss Ida Sutton has recently published a Report on Self-sterility in such fruit-trees as plums, cherries, and apples. It has been recognised that failure in fruit crops is not infrequently due to self-sterility. Two main questions were dealt with, (1) whether self-sterility is a simple Mendelian recessive character, and (2) whether self-steriles are fertile with the pollen of any other variety. So far, with regard to (1), the results show there is nothing which negatives the view that the property of self-sterility may be recessive, and in regard to (2) what East has called 'cross-incompatibility' is not confirmed by Miss Sutton's researches. The general conclusions arrived at by Miss Sutton are: (*a*) that many important commercial varieties of fruit trees set little or nothing unless cross-pollinated; (*b*) that for the pollination of these self-sterile kinds pollinisers must be planted; (*c*) that provided a variety produces plenty of pollen and flowers simultaneously with the variety which is intended to pollinate, any variety, at least of plums and apples, will probably serve for this purpose,

[10] *Science and the Nation*, 118.

apart from the special case of the Coe varieties of plums and their presumable co-derivative, Jefferson. We may mention the great success which is attending the establishment of a school of technical education and research by the Royal Horticultural Society at Wisley. This is maintained by liberal funds, and by means of its well equipped laboratories and extensive trial grounds it offers unique facilities for solving problems of great value as affecting the future of British horticulture. In sympathy with the work at Wisley private firms are also setting up laboratories of their own and employing men of high standing so that a just balance will be maintained between science and practice. By such means research will be stimulated and encouragement given to individual initiative which is recognised as fundamentally important in the advancement of science.

In schemes of intensive cultivation so ably advocated in reference to food production, it is well to bear in mind that it may be possible in some instances to go beyond what is necessary to achieve the object in view. Russell is of opinion that 'the more intensive the cropping the greater the opportunity for the various pests to live. . . Further, most pests have their parasites, and wholesale sterilisation may help the pest by destroying the parasites. Imms has recently noted two cases where this is said to have happened.[11] I may add a third instance of this character in the case of the Moth Borer attacking sugar-canes in the West Indies. For probably something like two hundred years the moth borer had been regarded as the most destructive enemy of the sugar-cane. Its life history was unknown until Lefroy, then attached to the Imperial Department of Agriculture, discovered the eggs which were deposited in a greenish cluster on the back of the leaves of the sugar-cane. The egg clusters were so inconspicuous that they had entirely escaped notice. The first steps were to employ boys to cut off portions of the leaves with the eggs and burn them. It was afterwards discovered that many of the eggs were parasitised, and the planters were thus unknowingly destroying the parasite, and practically increasing rather than diminishing the attacks of the moth borer. On the further advice of Lefroy the leaves with the egg clusters were not burned but spread out in the shade to enable the parasites to hatch out, with the result that in the later stages of the crop nearly all the moth-borer eggs were parasitised, and the loss in canes in that and the succeeding crop was largely reduced by natural means.

The progress made in the elucidation of problems in tropical plant pathology shows not only the necessity for well trained and experienced mycologists and entomologists, but also for the correlation and combination of knowledge gained in their several lines of study. It is suggested that research work should be organised on the broadest possible lines, and combine the biological services of the whole Empire. We have a first step in this direction in the Imperial Bureau of Entomology, with its headquarters at the British Museum. Those acquainted with the efficient work done by this Bureau and the excellent publications issued by it will very heartily welcome the establishment of the proposed Imperial Bureau of Mycology, to carry on its work on similar lines.

In this brief review I have endeavoured, however imperfectly, to place on record some of the activities that have taken place in the domain of Botany in recent years. It has only been possible to select a few of the most striking incidents where progress has been made. This has been done in the hope of arousing wider interest in work of prime importance as affecting the interests of the home country and the Empire. Botany in its widest aspects affects so largely the welfare of the human race that it is impossible to slacken our efforts. Advance has necessarily been slow, but the creative impulse of science cannot fail to bring in a large harvest of results. This may be possible by encouraging individual efforts, by organising active co-operation and in associating with us men who are practically grappling with difficulties that seem almost impossible to solve. I have attempted to show in what vast fields of enterprise botanical science has already rendered signal service. As regards the future, if we enlist the best intellects imbued with the true spirit of progressive research, we shall ensure a continuance of discoveries that have proved so effectual. We must also

[11] Address, 1916, p. 17.

call to our assistance some of that wonderful energy developed during the war and divert it to the great work before us.

Certainly one of the outstanding features that emerges from a record of botanical research during the last decade or two is the prominent position occupied by plant-breeding on Mendelian lines. In proof of this we have the numerous well-equipped plant-breeding institutes established and maintained by Government and private funds. Plant-breeding is now in the forefront in relation to the improvement of crops, and the value of it is officially acknowledged as 'a vital element in the national policy.' According to the Secretary of the Board of Agriculture, what we want 'are new races of plants adapted to intensify cultivation, and,' he adds, 'it is my deliberate opinion that an increase in the production of our land is much more easily attainable in that direction than in any other.'

The following Papers were then read :—

1. *Orchids of Hants and Dorset.* *By* Colonel M. J. Godfrey, *F.L.S.*

Malaxis paludosa Sw. New Forest, rare; only British orchid with epiphyllous buds. *Neottia nidus avis* L. Infrequent; essentially subterranean, only throwing up flowering stem to secure cross-fertilisation and dissemination of seed, sometimes flowering underground. *Listera ovata* Br. Common. *L. cordata* Br. Found near Branksome in 1895, perhaps introduced with pines. *Spiranthes autumnalis* Rich. Not infrequent, chalk downs and limestone pastures, also grows in sand. *Sp. æstivalis* Rich. Extremely rare, one locality in New Forest. *Cephalanthera grandiflora* L. Not uncommon; self-fertilised, once seen visited by *Bombus lucorum*. *C. ensifolia* Rich. Rare, absent from Isle of Wight. *Epipactis palustris* Cr. Not common, the only British *Epipactis* fertilised by hive-bees. *E. latifolia* All. Not uncommon. *E. violacea* Dur. Dusq. Very rare; both the latter fertilised by wasps. *Platanthera chlorantha* Rchb. Not common, frequent in Isle of Wight. *P. bifolia* Rchb. Rather rare. *Cœloglossum viride* Hartm. Rare, abundant near Winchester. *Gymnadenia conopsea* Br. Local, chalk downs, rarely in marshy ground; seeds protected from rain by closing of capsules. *Herminium monorchis* Br. Rare. *Ophrys aranifera*. Very rare. *O. muscifera* Huds. Rare; a hybrid with *aranifera* occurs in Kent. *O. apifera* Huds. Generally distributed, near Winchester tends to vary in the direction of *Trollii*.

Orchis mascula L. Locally abundant, rarely white. *O. morio* L. Locally plentiful; a specimen with three lips throws doubt on Darwin's theory that lip is compounded of one petal and two anthers. *O. ustulata* L. Rare; is said to smell like heliotrope. *O. latifolia* L. with ring-spotted leaves, *O. prætermissa* Druce, unspotted, essentially marsh plants, occur also (sparingly) high and dry on Winchester downs. *O. incarnata* L. Local, sometimes rose-pink fading white, sometimes red purple, sometimes bluish purple with carmine spots. A white variety is recorded from the New Forest. *O. maculata* L. abundant. *O. ericetorum* Linton. Usually regarded as a variety of *maculata*, occurs on peat bogs and damp heaths, has considerable claims to specific distinction. *Anacamptis pyramidalis* Rich. Frequent on the chalk, rarely pure white.

Natural Hybrids.—Most frequent in the genus *Orchis*, between *incarnata*, *latifolia*, *prætermissa*, and *maculata*. The following occur in the Winchester marshes: *incarnata* × *latifolia*, *incarnata* × *prætermissa*, *incarnata* × *maculata*, *latifolia* × *prætermissa*, *latifolia* × *maculata*, and *prætermissa* × *maculata*, except *incarnata* × *maculata*, which I have only seen in Anglesey, though it probably grows near Winchester. Marsh orchids grow intermingled, and are sufficiently similar for insects to visit them indiscriminately. *Bi-generic Hybrids.*—On Winchester Downs occur:—*Gymnadenia conopsea* × *Orchis maculata*, *Cœloglossum viride* × *Orchis maculata*, *C. viride* × *Orchis latifolia* (probably found nowhere else in the world), and *C. viride* × *Gymnadenia conopsea* remarkable as a cross between a very short-spurred and a very long-spurred orchid. *Aceras anthropophora*. Very rare if not extinct in Hants, has been seen fertilised by *Platychirus manicatus*, visiting the flowers to lay eggs amongst aphides.

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2. *On the Desert Flora of Western Egypt.* By Capt. H. Hamshaw Thomas.

During the spring of 1916 some months were spent in camp on the edge of the Libyan desert, about 25 miles north west of Cairo, and this afforded some opportunity of observing the flora of the region and the exceedingly unfavourable climatic conditions under which the plants grow. The winter rains are light, but in the spring very heavy dews occur at night, while during the day the pebbly soil becomes exceedingly hot. Vast stretches of gravelly desert occur, which, unlike the sandy and rocky desert of eastern Egypt and Sinai, are almost totally devoid of vegetation. A few individuals manage to grow in sandy pockets, while a small ephemeral *Erodium* succeeds in growing on the gravel.

On the sandy desert edge a number of dwarf tufted plants with stout tap roots occur. A specimen of *Calligonium comosum* was dug up but did not appear to confirm Volkens' estimate as to the length of its subterranean root system.

Attention is drawn to the effect of the peculiar sand-storms known as the 'Khamseen,' which occur in May and June just at the close of the growing period of the vegetation. By an intensely dry and strong wind, together with the eroding power of blowing sand, a large proportion of the younger shoots of the plants are killed and broken off. The results of these storms are shown in the dwarf, tufted habit of so many of the plants, especially in those lacking stout thorny branches.

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3. Mycorrhiza *and the* Ericaceæ. *By* M. C. Rayner, *D.Sc.*

Calluna vulgaris.

Experimental proof has been published in an earlier paper that the relation between this plant and its mycorrhizal fungus is an obligate one.

The facts are as follow :

(*a*) The fungus present in the root-mycorrhiza is distributed throughout the vegetative tissues of the shoot, and is present in the ovaries of the flower.

(*b*) Infection of the seed coats of the seeds takes place within the developing fruit, and the seeds are shed carrying the fungus.

(*c*) Infection of the new generation takes place at germination of the seed. Unless such infection occurs, the seedlings are unable to form roots and quickly perish.

New facts are now presented bearing on the following :

(1) The existence of a similar condition of '*obligate symbiosis*' in other members of the *Ericaceæ*. The genus *Vaccinium*.

(2) The bearing of the facts already known on the edaphic peculiarities of *Calluna*.

(3) The biology of the relationship. Possibility of nitrogen-fixation by the fungus.

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4. *The Morphology of the Stele of Platyzoma microphyllum. R. Br.* By John McLean Thompson, *M.A., D.Sc., F.L.S., F.R.S.E.*

In the materials of *Platyzoma* so far examined the stele was an unbroken medullated cylinder devoid of leaf-gaps or perforations. It possessed independent outer and inner endodermal sheaths between which lay in centripetal succession pericycle, outer phloëm, xylem and inner parenchyma. The pith was entirely isolated within the conductive cylinder having no ground-tissue connection with the cortex. In leaf-trace formation and departure the inner endodermis was in no way involved, and no point existed where the stele was not entirely enclosed by an outer endodermis.

It has been suggested that the pith of *Platyzoma* is the result of confluence and final isolation of a series of foliar 'pockets,' and is in reality of extrastelar origin, or is at least most reasonably interpreted as such, though, as a result of stelar reduction, it no longer communicates with the cortex. The stele itself has been considered reduced from an original solenostele by loss of internal phloëm and leaf-gaps As an alternative interpretation it has been suggested that

the medullated stele of *Platyzoma* may have been derived from a protostelic origin by the direct formation of an independent intrastelar pith and inner endodermis.

The evidence so far advanced seems inadequate to allow of a confident opinion regarding the nature and origin of the medullated stele of *Platyzoma*. For while no evidence of the intrastelar origin of the pith and inner endodermis has emerged to support the latter interpretation, the reduction theory has not been supported by the demonstration of cortical ' intrusion ' into the stele through stelar gaps, nor by the presence of stelar gaps and a solenostelic condition.

A recent investigation of a number of specimens of *Platyzoma* showed neither a solenostelic condition nor evidence of stelar gaps or inner phloëm. On the reduction hypothesis they might be considered evidential of the firm establishment of the reduced condition. On the theory of upgrade intrastelar differentiation they might be held to demonstrate how entirely intrastelar in nature as in location are the pith and inner endodermis.

On the other hand, as the stele of a small but incomplete specimen was followed forward from the broken base of the stem the pith and inner endodermis decreased until the latter was narrowed to a vanishing point, so that a medullated protostele was established locally. The pith again expanded and within it there arose *de novo* an inner endodermis. Further forward the pith diminished and the inner endodermis again narrowed to a vanishing point. For at least the second time in the history of this plant a medullated protostele was established locally, and on subsequent re-expansion of the pith, inner endodermis was again created *de novo*, and was subsequently maintained to the apex of the stem as an unbroken cylinder.

It is thus recognised that *Platyzoma* may become locally protostelic by reduction of the pith and loss of the inner endodermis. It may augment from within the stele itself an attenuated pith. In like manner it may develop an independent intrastelar endodermis.

Three definite states may exist in the stele of a fern.

(i) The original protostely may persist undisturbed throughout the entire ontogeny.

(ii) The original protostely may be transformed at an early stage in the ontogeny once and for all into one or other of the more elaborate stelar states.

(iii) The original protostely may recur in the ontogeny in ferns in which the advanced stelar state is not yet permanently established.

It is now suggested that *Platyzoma* provides an illustration of the third and apparently exceptional state in which the protostelic structure of the ancestry has not yet been definitely restricted to the 'sporeling' stages, but tends to persist in the mature organism. The stelar structure of the small specimen may be reminiscent of the steps taken in the initial transformation of the ancestral protostele, namely, the growth of a pith within the stele itself, and the inclusion of the bulk of this intrastelar pith within an independent internal endodermis created *de novo*. On this view the present medullated conductive cylinder of *Platyzoma* would be regarded as the high-water mark of stelar amplification so far reached for this plant, neither inner phloëm nor stelar gaps having been evolved.

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5. *The Northern Invasions of New Zealand, with Special Reference to Lord Howe Island.* By J. C. Willis, *Sc.D., F.R.S.*

Detailed study of the local distribution of species in New Zealand by zones of 100 miles in width reveals the probability that, in addition to the invasions at the north, from the Kermadecs, and from the south there was another invasion from the west, which likely followed the ridge upon which stands Lord Howe Island. By the usual method of prediction and subsequent verification it is then shown that the Lord Howe flora consists mainly of the genera of the three northern and western invasions; that the endemics of its flora are mainly in the older families of these invasions, and in the larger (older) families and genera of Howe; and that a large proportion of Howe species reach the Chathams, which are opposite to the probable centre of the western invasion of New Zealand.

WEDNESDAY, SEPTEMBER 10.

The following Papers were read :—

1. *The Relation of the Seed Plants to the Higher Cryptograms.* *By* D. H. Scott, *F.R.S.*

That the Seed Plants sprang from the Higher Cryptogams has been an accepted doctrine ever since evolutionary ideas were first entertained. The discovery of the Pteridosperms—Fern-like Palæozoic plants bearing seeds—has led many botanists to believe that the Spermophyta generally, or at least a great part of them, were ultimately derived from the Ferns. Sometimes, however, greater caution has been shown and only a 'common stock' postulated. Zeiller, always judicious, inclined to the latter hypothesis, but he, too, was much impressed by the Fern-affinities of the Pteridosperms, which he called 'Fougères à graines,' seed-bearing Ferns.

A reconsideration of the question has suggested a doubt whether the Pteridosperms ever were Ferns, and, further, whether the Seed Plants are not as ancient a race as any known phylum of the Higher Cryptogams (leaving the newly-recognised Psilophytales out of consideration). Though the point at issue affects the position of the Spermophyta as a whole, the question turns on the Pteridosperms, as they are the Seed Plants which bear the most manifest resemblance to a definite Cryptogamic stock.

The doubt was first raised by Prof. Weiss's observation that in the roots of *Lyginopteris oldhamia* the xylem-plate of the diarch rootlet is parallel to the axis of the parent root, as in Phanerogams, not at right angles to it, as in Pteridophyta. This, though a small point, seems to afford, so far as it goes, an absolute distinction, showing that in this respect the typical Pteridosperm, *Lyginopteris*, was a true Phanerogam.

Much stress has always been laid on the anatomical characters of Pteridosperms as evidence of an intermediate position between Cycadophyta and Ferns. It is remarkable, however, that no Pteridosperm is known to resemble in its anatomy any *contemporary* group of Ferns. We may arbitrarily compare *Lyginopteris* with *Osmunda* or *Heterangium* with *Gleichenia*, but these are mere analogies, for no one can imagine that there was any affinity between the genera compared. With Palæozoic Ferns, whether Primofilices or Marattiales, there seems to be little or nothing in common, from an anatomical point of view. The evidence may indicate a certain parallelism of development, but by no means supports filiation.

The resemblance in habit between Pteridosperms and Ferns is striking and obvious; it deceived almost all botanists, even Hooker himself, down to our own time. But in some cases, where the external likeness is greatest (*e.g.*, between *Alethopteris* and *Pteris*), we know that the internal structure was totally different; habit by itself is an illusory guide.

The seeds of Pteridosperms show no clear relation to Fern-sporangia, from which they are just as remote as those of Cordaiteæ or even Cycads. This is very different from the case of *Lepidocarpon* or *Miadesmia*, where the Lycopod relation is manifest. There is no reason to assume that the Pteridosperm-seed ever was like a Fern-sporangium; attempts to correlate them have depended on the aid of ingenious hypotheses with little basis of fact.

The pollen-sacs of Pteridosperms offer a better analogy with the sporangia of Ferns; they have generally been regarded as practically identical with the fructifications of Palæozoic Marattiales. We really, however know very little about the microsporangia; if they were bilocular, as there is some evidence to show, they were very distinct from Fern-sporangia of any sort.

It is suggested that the Pteridosperms (and *ex hypothesi* the Seed Plants generally) have always been distinct from any of the known phyla of Vascular Cryptogams; that they were not derived from the Primofilices of Arber or from any other group of Ferns recognised as such. The writer's object is to emphasise the distinctness of the Pteridosperms as an independent phylum, parallel in important respects to the Ferns, but of unknown and remote origin.

Zeiller thought that in the older Palæozoic rocks Pteridosperms were more

numerous in proportion to Ferns; there is no reason why they should not be, if both are equally ancient.

The enormous antiquity of highly organised Gymnospermous wood, *e.g.*, *Callixylon Trifilievi* in the Upper Devonian, *Palæopitys Milleri* in the Middle Old Red Sandstone, suggests, if it does not prove, that Spermophyta go as far back in geological history as any land plants of which the structure is known. Hugh Miller, three-quarters of a century ago, rightly insisted that the Gymnogens and Acrogens, as he called them, formed two parallel lines, running back into the unknown past. We cannot but believe that the two lines converged somewhere, but it may well have been at a point so remote that the common source antedates the origin of the Pteridophyta as hitherto understand.

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2. *On some New Types of Statocyte occurring in Vascular Plants.* By Miss T. L. Prankerd.

Further work has necessitated a slight modification of the definition of a statocyte given to the Section in 1915, and I now propose to define the term as a cell containing a body or bodies more or less free to move under the influence of gravity. The varied types may be characterised as follow :—

(1) The statoliths, or moveable bodies, are starch grains (*amylostatoliths*), simple or compound, larger than, smaller than, or the same size as the embedded grains of other tissues.

(2) The statoliths are starch-containing chloroplasts (*chlorostatoliths*).

(3) The statolith is a *crystal* of calcium oxalate usually occurring singly in the statocyte.

(4) Similar to (1), but the nucleus is differentiated in size and staining capacity from the nuclei of adjacent cells.

(5) Similar to (1), but the nucleus occupies a definite position in the cell, and though apparently free from the statoliths, moves with them.

(6) The nucleus is more or less united to starch grains, or starch-containing chloroplasts to form a gravitational unit (*nucleostatolith*).

(7) The statocyte is elongated in a vertical plane and contains a thick strand of protoplasm attached at each end. The strand contains embedded starch grains and a central nucleus, and is capable of swinging to the lower side of the statocyte should the latter be displaced.

Of the above (3), (4), and (7) are probably rare. The rate of movement varies very considerably in different plants; by far the highest yet discovered is that of the crystal statolith in the wheat plant, which is 600 microns per hour, *i.e.*, at least three times that of any other known statolith.

Quite independently of any function which may be attributed to statocytes, they are definite histological units, generally aggregated together into a tissue (*Statenchyma*)—a no less definite feature in plant anatomy.

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3. *The Flora of the District of the London Clay.* By Horace W. Monckton, *Treas.L.S., F.G.S.*[1]

The present communication deals with the Thames Basin only. The flora of the London Clay differs greatly from that on the other geological formations of the district, more especially from the flora on the chalk or on the Bagshot Beds.

The sedges are taken as an illustration. About twenty-eight species, and the hybrid *Carex axillaris*, grow on London Clay. *Eleocharis palustris, Carex vulpina, C. panicea, C. flacca, C. hirta,* and species of the flava and riparia groups are abundant. *C. pulicaris, C. stellulata, C. elongata, C. pallescens, C. Pseudo-Cyperus, C. sylvatica,* and *C. vesicaria* may also be mentioned.

In addition to the twenty-eight species referred to above, there are some twelve others recorded from the London Clay area. These include *Rynchospora,*

[1] See 'The Flora of the Bagshot District,' in *Journ. of Botany*, Vol. 57, September, 1919.

some species of *Scirpus*, of *Eriophorum*, and of the *Carex binervis* group, but these do not seem to occur where the London Clay forms the actual surface, and it is noted that a very slight covering of gravel or sand, too slight to mark on a geological map, is sufficient to alter the flora. Most of these twelve species appear to belong to the district of the Bagshot Beds and to have transgressed on to the London Clay area.

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4. *Monocotyledonous Features of the Ranunculaceæ with Special Reference to the Floral Structure.* *By* E. J. Salisbury, *D.Sc.*, *F.L.S.*

(*a*) Brief review of the vegetative and anatomical resemblances between the Ranunculaceæ and allied families and the Monocotyledons in general and the Helobiales in particular.

(*b*) *Floral Structure.*—The prevailing trimery of the Monocotyledonous flower and the occurrence of dimery as its normal derivative. The variation in *Paris quadrifolia*. Perianth structure and meristic variation in Ranunculaceæ and related families. The primitive character of the trimerous flower in the Ranales and the origin of the quincuncial type from the 3+3 condition.

The character of the andræcium. The complete or concealed trimery in Ranunculaceæ as exhibited by *Aconitum* spp.; *Anemone* spp.; *Eranthis hyemalis*; *Helleborus fœtidus*; and *Ranunculus hederaceus*.

Dédoublement in Alismaceæ and the frequency of this phenomenon on Ranunculaceæ. The numerous stamens of *Limnocharis* and *Hydrocleis*. Peripheral staminody in the male flower of *Stratiotes*. Extrorse dehiscence a feature of both Ranunculaceæ and Alismaceæ.

The character of the gynæceum. Apocarpy and large number of carpels (*e.g.*, *Alisma ranunculoides*). Occurrence in both Helobiales and Ranales of achenes and follicles. The special type of placentation in *Butomus* and *Nymphœa*. Nitzschke's recognition that the embryo sacs of the apocarpous Nymphæaceæ resembled most closely those of the Helobiales.

Striking similarity of the meristic variation in the gynæceum of polycarpic Alismaceæ and Ranunculaceæ. Periodic character of the curves. Trimery as exhibited by *Anemone* spp., *Clematis vitalba*, *Ficaria verna*, *Ranunculus aquatilis*, &c.

The probable character of the primitive Ranalean flower.

Joint Discussion with Section L on the Teaching of Science, at which the following Paper was read:—

5. *Method and Substance of Science Teaching: The Neglect of Biological Subjects in Education.* *By* Sydney Mangham, *M.A.*

Those University teachers who are responsible for conducting classes in experimental plant physiology will probably agree that one of the many difficulties to be faced is the fact that students, during their first and even their second year, frequently do not gain from their courses in chemistry and physics sufficient of that type of instruction which is really helpful in their botanical work. It would, of course, be unreasonable to ask teaching chemists and physicists to keep in mind primarily the requirements of biology, but would it not be possible for them to give the special needs of their biological colleagues more adequate consideration? Since all life exemplifies the operation of chemical and physical laws, is it not in the best interests of a liberal scientific education that *all* science students should come to realise the biological significance of these laws? Is it absolutely necessary to labour the more formal and mathematical aspects of physics and chemistry in the early terms of University training? Could not a *general and experimental* treatment of such subjects of biological and technological importance as diffusion, osmosis, capillarity, surface tension and surface energy, adsorption, the colloidal state of matter, enzyme action and the chemical nature and potential energy of sugars, starch, fats, proteins, &c., be introduced into first-year courses without detriment to the physical or chemical training of the student? More advanced, specialised

and mathematical treatment could follow later, but the inclusion in the first year of the above interesting and important topics, treated experimentally, would ensure that students not proceeding further with biology would at least have had their attention directed to some of the most fundamental considerations applicable to the living world around them, while students continuing biological courses would have received *timely* assistance for which they, and their teachers, would have real cause to be grateful.

Clearly all that is necessary for the achievement of such a desirable object is close and sympathetic co-operation between all University science teachers. As far as individual colleges, &c., are concerned there is no valid reason why this could not be secured almost immediately, for by occasional meetings of the full staffs it could readily be ascertained what are the special aims, working requirements, and points of contact of the several branches of science represented or about to be represented, in the curriculum.

In the afternoon a Sectional Excursion took place to Shell Bay.

THURSDAY, SEPTEMBER 11.

The following Paper was read :—

Root Pressure. By Professor J. H. PRIESTLEY, *B.Sc.*

An attempt is made to show that in the literature of this subject there already exists the data for a theory of the mechanism of root pressure which would appear reasonably adequate.

This theory would enlist the services in the mechanism of root pressure of (1) osmosis for the diffusion of water from root hair to the parenchyma bordering on the xylem; (2) the structure of the endodermis; (3) the behaviour of a colloid gel in respect to its varying permeability towards water.

It is suggested that this theory should be acceptable for the moment as embodying the least amount of unverifiable hypothesis, and it is pointed out that it indicates the need for a considerable amount of further anatomical and physiological research.

Joint Discussion with Section M on Forestry Problems, opened by the following Paper :—

The Afforestation of Water Catchment Areas.
By Professor AUGUSTINE HENRY, *M.A.*[1]

The afforestation of water catchment areas is a hygienic measure as well as a means of increasing the timber reserves of the nation. Many towns obtain their water supply from catchment reservoirs constructed to impound the water falling on upland and sparsely peopled tracts. Such gathering grounds in the Pennine range supply most of the great centres of population in Lancashire, Yorkshire, and Derbyshire. Other catchment areas are situated in Wales, Cornwall, and a few other districts in England, and in many parts of Scotland. In many cases the water authorities have only leased the water rights and have not acquired the ownership of the gathering grounds. For the prevention of pollution of the water, they have relied mainly on the 61st Section of the Waterworks Clauses

[1] The subject of the afforestation of water catchment areas in Great Britain and Ireland is fully treated in chapters vii.-xii. of *Forests, Woods, and Trees in relation to Hygiene*, by Professor Aug. Henry, published in November, 1919. These chapters are illustrated with sketch maps, plans, etc.

Act of 1847, which makes it penal to lead sewage into or wantonly to defile the reservoirs and the streams feeding them. This protection is inadequate, as anything that happens to be on the gathering ground may be carried down into the reservoir in time of floods or heavy rains. When houses or farms exist on the gathering ground, serious impurities, such as the excreta from a typhoid case or the contents of a cesspool on a farm steading, may be swept into the reservoir. It has been found difficult in practice to compel farmers living near a stream in a watershed to re-arrange their middens, cow-houses, &c. The diversion of sewage from farms by drains is scarcely an adequate protection.

To prevent pollution of the water supply from these gathering grounds the entire area over which rain is collected ought to be owned by the authority responsible for the waterworks, and should be managed solely in the interest of the water consumers.

There is one means by which water catchment areas can be effectually guarded against pollution and at the same time be put to profitable use, and that is afforestation. In considering the advisability of afforesting a watershed, it need not be assumed that the entire area should be covered with trees. Questions of aspect, depth and nature of soil, shelter from wind or exposure, must be taken into account in determining where and what to plant. It is probable that the proportion of any gathering ground that can be planted with advantage will be found to vary from 10 to 70 per cent. of the total. On most catchment areas which attain over 1000 feet elevation a combination of grazing and forestry must be resorted to. Only the lower zone and the sites with favourable soil are suitable for planting.

The main difficulty of afforestation on a large scale in England lies in the necessity for the acquisition of the land by some corporation or State authority, who would be bound to carry out the work on the only lines that would ensure success, namely, the planting to be spread over a term of years, to be uninterrupted, and to be carried out in large blocks, in no case of less than 500 acres each. It will be difficult to induce private landowners to undertake, out of their diminished incomes, afforestation schemes on the large and continuous scale that is essential to success.

In the case of water catchment areas belonging to corporations, the question of continuous ownership is solved; and the agreement entered into on August 18, 1914, by the Liverpool Corporation and the Development Commissioners is a workable financial scheme that can be adopted generally. The Treasury provides the money necessary for planting, while the Corporation gives the land and pays the recurring annual expenses of management and taxes. In this partnership the produce of the forest will be ultimately divided between the two parties in the proportion of the capital invested by each. In this way the profit or loss accruing from the plantation will be fairly shared between the State and the Corporation. Afforestation should be imposed as a necessary duty on all the water authorities who obtain their supply from gathering grounds; in other words, each corporation ought to be compelled to carry out a planting scheme as soon as the Government shall issue a loan for the initial expenses of planting.

The Forestry Reconstruction Committee in their Report say: 'We consider it should be an invariable rule that on catchment areas all land which will produce a crop of marketable timber should be afforested. Many of the corporations are still engaged in meeting the capital outlay which their water-supply systems necessitated, and for that reason are unwilling to place further burdens on the present for the benefit of future generations.' They recommend that the local authorities be assisted by grants or by a scheme of proceeds-sharing. Mr. Joseph Parry, long the engineer in charge of the Liverpool Waterworks, considers the proceeds-sharing scheme to be less favourable than the Liverpool agreement referred to above, and to be surrounded by conditions which he would not advise any local authority to accept. In his opinion the Forest Authority should be allowed to take over the whole business and pay the local authority a fair rent for the use of the land.

Only in a few cases has the work of afforesting these gathering grounds been taken up seriously. Leeds, Liverpool, Manchester, and Birmingham have planted on a considerable scale. The other municipalities have done very little.

The enormous extent of these gathering grounds has not hitherto been

recognised. Information obtained by an inquiry during the past two years by Prof. A. Henry is summarised in the following table :

Country	Total extent of Gathering Grounds			Extent owned by Local Authorities	
	Local Authorities	Companies, &c.	Acres	Local Authorities	Acres
England and Wales .	127	14	591,336	64	140,305
Scotland . . .	78	—	243,624	16	27,829
Ireland . . .	46	1	93,835	9	15,282
Total . .	251	15	928,795	89	183,416

To sum up, the water catchment areas still privately owned should be compulsorily acquired, either by the Corporation or by the State, in order to preserve the purity of the water supply. As soon as acquired they will form convenient centres for afforesting the hill grazing zone, which lies between the agrarian zone utilised by agriculture and the moorland zone on which trees can never be profitably planted. Legislation is about to be enacted which will enable the State or the municipalities to acquire these gathering grounds at a reasonable price. The splendid success of the plantations made during the last twenty years by the Liverpool Corporation on their gathering ground at Lake Vyrnwy can be rivalled by other municipalities deriving their water supplies from gathering grounds in the mountainous districts of Wales, Northern England, Scotland, and Ireland

In the afternoon a Sectional Excursion to the New Forest took place.

FRIDAY, SEPTEMBER 12.

Joint Meeting with Section D—see p. 211—at which the following Papers were read :—

1. *The Development of the Bute Laboratory and Museum.* *By* L. P. W. Renouf.

2. *On a Graded Series of Forms in Matthiola.* *By* Miss E. R. Saunders.[1]

Matthiola incana type is densely hairy throughout. Certain glabrous forms, well known to gardeners as the wallflower-leaved strains, are absolutely devoid of hairs. Besides these glabrous strains there is a rare variety intermediate between them and the type. Matings between this half-hoary form and the glabrous strains produce a number of intermediates, which with the parent forms and the type constitute a graded series as regards hairiness, in which the familiar garden forms represent the end terms. All the partially hairy grades exhibit a progressive development of the hairy character, the range in one grade overlapping that of the next in the series. Each grade has a distinct genetic behaviour, but in one grade, and perhaps others, the appearance suggests that limiting physiological conditions may be in question. Inter-relations between the grades are explicable on the supposition of multiple allelomorphs.

[1] To be published in *Journ. of Genetics.*

3. *Mutational v. Recapitulatory Characters.* *By* R. Ruggles Gates, *Ph.D.*

The cytological work on mutation has led to the view that each mutation is the result of a nuclear change in a germ cell. In the last analysis this is either a physical or a chemical change in the chromosomes. A chemical change in one chromosome results in a new Mendelian character, which is handed down to later generations just as the descendants of that chromosome are transmitted. Mitotic cell division, by equally splitting all the chromosomes, ensures that the change will be represented in every cell; and so a mutation, in plants at least, usually affects every stage of the ontogeny. Mitosis may thus be looked upon as an hereditary process.

In contrast to mutational or cell characters, which arise in the nuclei and modify every stage of the ontogeny, we place recapitulatory characters, which arise through the impress of the environment, usually involve adaptation to new conditions, are gradually developed, and in becoming permanent involve the principle of inheritance of acquired characters.

These two classes of characters therefore differ in (*a*) their manner of origin, (*b*) their relation to organic structure, and (*c*) their relation to phenomena such as recapitulation, adaptation, distribution, and inheritance. The theory of antithetic alternation of generations, which is widely held as regards Archegoniate plants, implies a gradual lengthening in the sporophyte through the addition of cell divisions to its sub-terminal stages. This can hardly be supposed to have resulted from an alteration in the cell unit.

Characters which show recapitulation, as in the seedlings of Gymnosperms, or the innumerable cases in animal larvæ, imply a lengthening in the life cycle in connection with adaptation to new conditions. Such characters could not have arisen through a mutation, for that would modify every stage instead of *adding* certain stages as it does. The attempts of many zoologists to explain away the remarkable facts of recapitulation have not been markedly successful. The apparent contradictions of von Baer's law of animal development are partly due to the occurrence of mutations in organisms which already show recapitulation.

Thus both mutational and recapitulatory characters are necessary to account for the phenomena of evolution. The one is nuclear in origin and centrifugal in effect; the other, extrinsic in origin and ultimately centripetal in its effect in the organism. The recognition of both types of characters involves the limitation of the cell theory and the admission of the neo-Lamarckian factor.

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4. *The Fungal Species.* *By* William B. Brierley.

In mycology the species group is at present conceived as 'all those individuals possessing an *essentially similar morphological facies.*' This definition is based on the following assumptions :—

1. The essential specific characters of an organism are of a morphological nature.
2. The morphological characters are constant and hereditary.
3. The essential morphological characters may be recognised and evaluated by sight in one specimen of one generation.

It is, however, known that the Linnean species or 'Linneon' in fungi may consist of a group of elementary species or 'Jordanons,' and that each of the latter may contain one or more true 'species' or pure lines. It has also been demonstrated that the morphological facies of a 'species' is only constant under constant conditions, and that development in a changed environment may give rise to different morphological characters. The morphological facies of a fungus is therefore merely the visible expression of the resultant of the interaction of the physiological constitution of the organism, which ultimately is of physico-chemical nature and of the physico-chemical factors of the environment.

The true species concept is therefore physiological and not morphological, and the species group is defined as 'all those individuals possessing an *essentially similar physiological constitution.*'

The physiological constitution of fungi may only be ascertained and compared

by means of quantitative data obtained from the physiological and chemical reactions of the organisms developing under standardised physico-chemical conditions; and a species only has value if diagnosed in such terms.

There is no evidence free from doubt to indicate how species have arisen in the fungi. The most weighty studies are those on the induction of heritable alterations, but most of these are uncritical, and in the absence of knowledge concerning the genetical constitution of the subject-organisms judgment must be reserved in all cases.

The subsequent transactions were as follow :—

5. *Lecture on* Spartina *and Poole Harbour.*
By Professor F. W. Oliver, *F.R.S.*

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6. *Demonstration by* Sir Daniel Morris *of the Collection of Coniferæ grown locally.*

Informal Discussion arising out of Professor Priestley's *Paper on Root Pressure.*

Exhibit of Microscopic Preparations by Miss Prankerd.

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7. *Report of Committee on Experimental Studies in the Physiology of Heredity.*—See Reports, p. 124.

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8. *Report of Committee on Sections of Australian Fossil Plants.*
See Reports, p. 124.

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9. *Report of Committee on Australian* Cycadaceæ.
See Reports, p. 125.

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10. *Report of Committee on the Organisation of Research in Plant Pathology in the British Empire.*—See Volume for 1918, Reports, p. 56.

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11. *Report of Committee on Training and Research in Horticulture.*

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12. *Report of Organising Sectional Committee on the consideration of matters relating to the War or Reconstruction after the War.*

Section L.—EDUCATIONAL SCIENCE.

President of the Section: Sir Napier Shaw, M.A., Sc.D., F.R.S.

TUESDAY, SEPTEMBER 9.

The President delivered the following Address :—

Educational Ideals and the Ancient Universities.

A Presidential Address before the Educational Section of the British Association is an undertaking that might fairly daunt the bravest of those who are really acquainted with its difficulties; the vast range and variety of the problems of education; the enormous amount of effort that is already expended upon them; the torrents of advice and criticism that are offered by those who are familiar with the details of the various curricula, who know how things ought to be done; if I had had time and capacity to become acquainted with all these things I suppose I must have avoided the duty of making an address. It is, perhaps, the detachment of my present position from any responsibility for details which gives me the courage to recall experiences, now twenty years old, acquired during a lengthy service in various capacities at Cambridge, and matured by twenty years of the consciousness of the dire need of educational discipline and training for those whose business it is to use science in the service of the State.

With a certain amount of assurance I can even be glad that I am not in touch with the educational controversies of the hour, and confidently trust that my deficiencies will be made good by the contributions, of those who know, to the discussions which will take place in the Section, but the difficulty that I cannot get over just now is that, from the unavoidable circumstances of the present time, a presidential address is a 'back number' before it is delivered, for the simple reason that, according to tradition, it must be printed in advance. In this particular year there is an almost immeasurable gulf of experience between the time of my appointment in 1917 and the delivery of this address; the President himself is in many ways a different person from him who undertook the duty of addressing you two years and a half ago.

At that time I had been a good deal moved by the wearying controversy about the relative merits of classics and science in education, because the physical sciences as taught were such a doleful misrepresentation of the spirit of inquiry about the Universe which has moved men in all ages and is as clamant to-day as ever. The mysteries of the firmament, the midnight sky, the storm and calm, the earthquake and the thunder, the sunshine, the rainbow and the halo, the intolerable heat and the pitiless cold, the mariner's compass, the aurora and the mirage are still as wonderful as ever to the wayfarer and the seafarer, and even the dweller in towns wants to know more about them. Yet our educational system, as I knew it, passed all these subjects by and offered instead the determination of the specific heat of copper, with other things that the specific heat of copper stands for. The same, I believe, is true for many of the most interesting subjects of scholarship in

ancient and modern civilisations, learning and languages. And if an inquirer, young or old, should ask whether, if he went there, the great Universities could tell him all about the things of wonder or of beauty that he is conscious of, or about the reminiscences of past generations that he finds around him as he travels through life, he could only be told that in consequence of the perverse malignity of external circumstances they had no money to devote to his enlightenment. The capacity would be there in abundance but not the means. In three years they would put him in a position to pursue intelligently for himself if he pleased any of the subjects in which his interest had been excited but the facilities for education would extend only to the point where his interest began.

So I wrote a little pamphlet on the 'Lack of Science in Education with Some Hints of What Might Be,' and when I was invited to occupy this Chair I thought I might be of some service to Education if I pressed the subject further and endeavoured to show how, in spite of the goodwill of nearly everybody concerned, the peculiar constitution of our chief Universities was really standing in the way of the lofty ideal of higher education which must find expression if the education which we all want is really to come to pass in this country.

Circumstances have already vastly changed. Committees have sat upon the Teaching of Science and the Teaching of Modern Languages. A great Education Act has been passed and the poverty of the Universities has overstepped the limits of starvation, and a Commission of Inquiry is promised. So we are now on the high road to making presidential addresses matters of quite subordinate interest. Still, you may be interested to hear what I wrote, two years and a half ago, in explanation of the peculiar difficulties of our educational system, so here it is. It makes a good deal of play of a certain scene in 'The Merchant of Venice,' which I shall beg you to regard, for a few minutes only, as a satire upon the state of the Universities in the spacious times of Queen Elizabeth, after a period of magnificent activity on the part of founders and benefactors and after a succession of statutes for the Universities made by successive monarchs for the governance of those institutions which were then recognised as of the highest importance in the State. Such a period of reconstruction seems to have come again in our time, and the satire, if it be one, is in some important respects as true to-day as it was three centuries ago.

I was arrested by the curious sentiment 'If to do were as easy as to know what were good to do chapels had been churches and poor men's cottages princes' palaces.' I wondered whether Shakespeare intended this passage to convey to the subtle reader an idea of Portia's youth and inexperience, or perhaps to indicate that Portia was in fact intended to personify a liberal education. For other subjects of human activity her statement is palpably absurd. All the experience of the British race indicates to us that the acute divisions between people arise in discussions as to what were good to do; the actual doing is easy if the preliminary question 'what were good to do' is really decided. Can any one doubt that after our experience of the war? For the most part it is only ingenuous youth that finds it easy to know what were good to do, and perhaps there is also a note of the ingenuousness and inexperience of youth in the sweeping desire for the conversion of chapels into churches and poor men's cottages into princes' palaces.

But if it were education that Shakespeare was thinking about, chapels and churches, poor men's cottages and princes' palaces are not inappropriate in that connection; the sentiment stimulates the imagination. Certainly in education to know what were good to do does seem in practice to be infinitely easier than to do.

From time to time the newspapers are full of reports of conferences, meetings, congresses, and assemblies all fully assured that they know what were good to do. Men of science justly claim to be humanists and recognise the helpfulness of literary studies in their purpose; classicists recognise the need of a knowledge of science; everybody is agreed that many things ought to be done and yet very little happens: our scheme of education is still unsatisfying; why?

That is the question which I propose for your consideration. Why is it that all the pious opinions about education come to nothing or to so little?

First of all it must be noted that the resolutions and proposals are not addressed to anybody in particular. Presumably they are intended to form public opinion, but public opinion has no authoritative voice with those who are in charge of the higher educational institutions. The resolutions are sent out like wireless signals from a ship at sea. Any educational institution with a receiver tuned to the proper wave-length can take them in, but if the receiver is not tuned or the operator is inattentive nothing happens. Those who are in charge of the administration of our justice when they want to settle a disputed point do not hold a meeting and pass a resolution to be printed in the 'Law Times' or other forensic journals. They put a yellow paper in the post with blue lines drawn cross-wise over it, with somebody's name and address more or less legibly written thereon, and twopence in addition to the postage. The postman does the rest. The recipient is reminded of his duty by the laconic exhortation at the end 'Herein fail not.' There is no such simple process with educational procedure. We are accustomed to regard educational institutions as somehow in the aggregate responsible for what we know as education, but there is no corporate responsibility for the aggregate of our higher educational institutions. There is no door at which a postman could deliver a registered letter of business.

We may, I think, agree that if we wish for ideals in education in this country we must find them in the Universities. If the Universities give the encouragement of their example and their licence to teach only to men and women who are really educated in the best sense of the word their influence will leaven the whole of education throughout the country; and, on the contrary, if when they leave the Universities the men and women who have to teach, or to control teachers, are themselves imperfectly educated, it is hopeless to expect a well-balanced living educational system. Among the Universities, for reasons good or ill, into which I need not enter, the older Universities of Cambridge and Oxford have a preponderant influence.

And to my mind the outstanding characteristic of the organisation of the older Universities is the want of any recognised door by which their corporate responsibility can be reached. In each case the University is itself a corporate educational institution which includes some twenty Colleges which are also separate corporate educational institutions. You never can tell whether the persons with whom you have business are the University or the Colleges, and it is quite possible that when you think to address the one you find yourself confronted with the other. The Universities in their corporate capacity are constrained by statutes and traditions handed down by our forefathers to look on in comparative impotence while their ideals are distorted or concealed by the interplay of the interests of the many corporations of which they are composed. The whole complex scheme of management forms a sort of craft or mystery which very few even of the initiated really comprehend.

In January of the year when I was writing (1917) I came across two delightful examples of this. The Headmasters' Conference (which consists of men with some academic experience) passed a resolution to the effect that Greek should no longer be required for the entrance examination of the Universities of Oxford and Cambridge, and thereupon the Master of University College, Oxford, spent half a column of 'The Times' in explaining that the University of Oxford had no entrance examination at all.

In the same newspaper Sir William Ridgeway, who is Professor of Archæology at Cambridge, and might therefore be supposed to know something about Oxford, wrote a column about Graduate Research, which brought a reply of another column from Professor Percy Gardner, now of Oxford, formerly of Cambridge, to say that so far as Oxford is concerned 'Professor Ridgeway's letter is nothing but a tissue of blunders.' Writing about the same time the Master of a Cambridge College explained to me that everything that appeared in the newspapers about Cambridge was wrong.

This veil of incomprehensibility, the claim to a sort of impenetrable freemasonry or mystery about matters of national concern, is very perplexing for those who want things done in education but do not know the technicalities of the

Universities. It completely hides any door at which the reforming postman might wish to knock. The people who want things done become shy, embarrassed, and intimidated by the people who 'know.' If you want anyone to take in a suggestion you have to seek what an Italian dramatist has called 'la porta di dietro.'

Somehow or other you must get at the Colleges as well as the University. Otherwise you may find yourself addressing the Vice-Chancellor on a subject which is the concern of the Colleges, or addressing the College tutor upon something over which he has no control. For those who know, of course, the explanation is quite simple. The schoolmasters do not want Greek to be compulsory in the entrance examinations of the Universities. We are told that at Oxford, and it is equally true of Cambridge, the University has no entrance examination at all, from which it would appear that the headmasters were at least very ill-informed about the Universities whose practice they wished to modify. Yet the headmasters know perfectly well that their boys, at any rate, have to pass an entrance examination before they can be admitted to either University.

What is true, for Cambridge at least, is that the University *qua* University has no examination for entrance; it is obliged by its statutes to accept as a member without any question anyone presented by the recognised authority of a College, regardless altogether of his qualification or disqualification for a University career. It is a very remarkable arrangement. The University makes no inquiry as to a student's fitness to profit by the educational system of the University : it leaves all that to the Colleges, and many, if not all, of the Colleges have an entrance examination. So I offer this paradox for the logician who is interested in higher education.

The University consists of the members of its constituent Colleges and a few others. At the discretion of the several Colleges, or the non-collegiate students' board, seventy-five per cent. of the members of the University are required to pass an entrance examination before they are accepted for presentation to the University for matriculation. There are at least four examinations of the University which are accepted by Colleges on occasions in lieu of their own entrance examinations. Yet there is no extrance examination for the University.

And this does not end the matter. The University becomes a controlling body rather than an educational institution with a definite purpose and programme. The regulations for its students are nearly all of them of a negative character. The discipline and the *regimen* of the University rest upon the assumption that a student desires to secure from the University not so much attainment as a stamp for his attainments. A member of the University cannot be admitted to a degree unless he has satisfied certain conditions of residence and also satisfies certain examiners; his name is not accepted for the final examination unless he has satisfied certain other examiners. There is nothing in the regulations or administration of the University to secure that a matriculated student shall study, or aspire to take a degree. He might live on in idleness and ignorance for the rest of his natural life; the University has no choice in the matter so long as his College pays the periodical fees. It trusts to the Colleges to see that idle or unsuitable undergraduates are invited to go elsewhere.

Here we have one of the many instances of the division of jurisdiction between the Colleges and the University which hides the ideals of our system of higher education in an impenetrable fog.

The University is governed by the Colleges according to a system which goes back to the time when the 'Merchant of Venice' was written, so let us revert to the conversation between Portia and Nerissa which expounds the lottery of the caskets in the well-known scene. The position of the University in the matter of the selection or rejection of its members is exactly that which Portia bewailed to Nerissa. Let me invite you to regard the episode of the caskets as a figurative representation of the lottery by which the University of Cambridge selects those upon whom she bestows her inherited riches—'lucem et pocula sacra.' Cambridge, like Portia, the heiress of all the learning of the good and the great, bound by the fantasy of her ancestral tradition never to choose for herself.

Let us think of Portia as the Vice-Chancellor of the University of Cambridge desiring above all things the advancement of learning and of Nerissa as a Proctor whose duty it is, as representing the Senate, the collective body of members of the Colleges, to see that the statutes and ordinances are duly attended to. Listen to the conversation which begins with the exclamation, 'By my troth, Nerissa, my little body is aweary of this great world,' a remark with which I feel sure many a Vice-Chancellor has opened many a conversation with many a Proctor. In accordance with the usual practice in dealing with classical literature I have added a few notes.

DIALOGUE between Portia (Vice-Chancellor) and Nerissa (Proctor), the representative of the Senate of the University through which the Colleges exercise their control.[1]

Portia (V.C.)—'By my troth, Nerissa, my little body is aweary of this great world.'

Nerissa (Proctor).—'You would be, sweet madam, if your miseries were in the same abundance as your good fortunes are: And yet, for aught I see, they are as sick that surfeit with too much as they that starve with nothing.[2] It is no mean happiness, therefore, to be seated in the mean: superfluity comes sooner by white hairs, but competency lives longer.'

Portia (V.C.).—'Good sentences and well pronounced.'[3]

Nerissa (Proctor).—'They would be better, if well followed.'

Portia (V.C.).—'If to do were as easy as to know what were good to do, chapels had been churches and poor men's cottages princes' palaces. It is a good divine that follows his own instructions: I can easier teach twenty what were good to be done, than be one of the twenty to follow mine own teaching. The brain may devise laws for the blood, but a hot temper leaps o'er a cold decree: such a hare is madness the youth, to skip o'er the meshes of good counsel the cripple.[4] But this reasoning is not in the fashion to choose me a husband. O me, the word "choose!" I may neither choose whom I would nor refuse whom I dislike; so is the will of a living daughter curbed by the will of a dead father. Is it not hard, Nerissa, that I cannot choose one nor refuse none?'

Nerissa (Proctor).—'Your father was ever virtuous; and holy men at their death have good inspirations: therefore the lottery, that he hath devised in these three chests of gold, silver and lead, whereof who chooses his meaning chooses you, will, no doubt, never be chosen by any rightly but one who shall rightly love. But what warmth is there in your affection towards any of these princely suitors that are already come?'

Portia (V.C.).—'I pray thee, over-name them; and as thou namest them I will describe them; and, according to my description, level at my affection.'

We may omit the description of the suitors as they are none of them to her taste, and pass on to Nerissa's remark.

Nerissa (Proctor).—'You need not fear, lady, the having any of these lords: they have acquainted me with their determinations; which is indeed to return to their home and to trouble you with no more suit,[5] unless you may be won by some other sort than your father's imposition depending on the caskets.'

Portia (V.C.).—'If I live to be as old as Sibylla, I will die as chaste as Diana, unless I be obtained by the manner of my father's will.'[6]

As an additional note I should like to suggest that the successful suitor Bassanio with his magnificent thoughtlessness is typical of the Public-School boy for whom the University always plays a soft air when the caskets are in view, but I feel sure my scholastic hearers would detect an anachronism.

I need hardly say that I should not spend so much time over what may

[1] The scene is at Belmont, which is no doubt a poetic name for Market *Hill*, adorned by the University Church in Cambridge.

[2] The University has always been recognised as very poor.

[3] Note the lapse into the sententiousness of the habitual examiner.

[4] This is obviously a reference to University life.

[5] The older Universities have often been thought to be too exclusive.

[6] This is doubtless allusion to the exemplary patience with which the University accepts the 'non placet' of the Senate.

seem to many of you far-fetched, and perhaps unseemly jesting, if I did not believe that this fantastic view of the lottery of the caskets contains the suggestion of an element in the governance of our highest educational institutions which deserves your gravest and most serious consideration. What I have in mind at the moment is the unforeseen and undesired result of the competition of the Colleges within the University itself as quasi-independent educational institutions. It is this small matter, from some points of view of quite minor importance, which, so far as I can see, prevents our great Universities from taking the leading part which they might take in exemplifying the ideals of a co-ordinated national system of education, and makes the success or failure of those great institutions something of the nature of a lottery. They may offer ten thousand different avenues from matriculation to a degree, and yet the student may find himself imperfectly educated in the end.

One may, indeed one must, picture to oneself the idea of the Colleges as a number of educational institutions co-operating in an avowed and transparent common purpose of the University to display the highest educational ideals. So I think if they were willing they might be, without any sacrifice of their individuality or of those magnificent traditions which have fulfilled the high purpose of their pious founders and benefactors. Let us keep that picture for a while in mind.

I have taken out from the Cambridge University Calendar for 1918 a list of subjects selected for teaching in the University and Colleges with the number of Professors, Readers, Lecturers or Teachers assigned to the several subjects. The numbers are given in an Appendix.

If any of my hearers has ever attempted a similar task he will agree with me that the compilation of the list from the information given for the Universities and Colleges is not by any means an easy matter, because the specification in so many instances is indefinite in various ways; but I am not less qualified than the average inquirer, not actually resident in the University, to understand what the information means, and it is for the average inquirer presumably that the Calendar is published. I am, however, not intending to refer to small details, so I hope that the inevitable imperfections, even in so imperfect a year as 1918, will not seriously affect what I have to say.

I find that there are 175 University teachers (professors, readers, lecturers, etc.) and 176 College lecturers. These two classes are certainly not mutually exclusive. In the natural sciences particularly the same names appear in both lists, but, be that as it may, I find that the 175 University teachers between them deal with 73 subjects, an average of $2\frac{1}{2}$ per subject, and are distributed between subjects in the following manner :—

Number of University teachers assigned for a subject

9 8 7 6 5 4 3 2 1

Number of subjects which have the number of teachers specified in the upper line

2 3 1 4 1 3 8 10 42.

The 176 College lecturers deal with only 23 subjects, an average of $7\frac{1}{2}$ per subject. They are distributed as follows :—

Number of College lecturers assigned for a subject

33 30 23 18 17 10 5 3 2 1 ?

Number of subjects that have the number of teachers specified in the upper line

1 1 1 1 1 1 3 1 3 9 6

Here we see at once a great difference between the educational systems. The University is obviously striving to meet as far as possible its higher educational responsibilities. There is great differentiation of duty; 42 teachers are responsible each for a single subject; there are only two cases in which a subject has so many as nine teachers. Whereas in the Colleges the tendency is for the same subject to have a great number of exponents. The favoured subjects are classics 33, mathematics and natural philosophy 30, history and economics 23, natural sciences 18, divinity 17. All those subjects are provided for, to some extent at least, in the programme of the University.

There may be and indeed must be some differentiation within these totals, but it is a differentiation which the College authorities do not think it necessary to disclose. Whatever allowance may be made for that, I think it is obvious that the Colleges tend to repeat many times over a stereotyped form and not to distribute their energies over subjects which for lack of funds or some other reason are not represented in the University list. The list of subjects indicates that the Colleges select the commoner subjects, and are particularly partial to those subjects which do not require any special provision as regards accommodation or equipment. Three subjects appear in the College list and not in the University list—namely, Modern Greek, Celtic, and Military History. Why these subjects are so favoured we need not inquire, but we may be sure that the 176 College lecturers are in themselves fully competent to represent subjects of profound human interest which the University disregards for want of means. That it is the system and not the lecturers that account for this convergence upon a few subjects was evident enough during the war, when Cambridge lecturers were to be found among the most proficient and successful workers with their brains in many departments of activity. The needs of peace are not less urgent than the needs of war; what we have learned in war we ought to practise in peace.

No one can think that the distribution of teachers and subjects would be what it is if the educational system of the University and the Colleges were under the control of a single competent body bent upon manifesting a true ideal of the use of educational endowments, whether in money or men.

Suppose, for example, that the Council of the Senate were recognised as responsible to the country for the educational system of the University and the Colleges jointly; that, once appointed, they were freed from the referendum of every item of their procedure to the lottery of a vote in the Senate. Imagine what would happen if the University really had an entrance examination and the Colleges had to select their members from among the successful candidates. One may speculate upon what such a body would produce, but it is hardly imaginable that they would plump for concentrating so much of the College teaching in general terms upon classics, mathematics, history, and divinity.

And, in support of the contention that diversity of intellectual effort is a pertinent consideration, I would point out that if recondite subjects are to be studied at all it must be at our own great centres of learning. If there is any part of the world where old customs are dying out, or interesting species becoming rare or extinct, it is for highly centralised countries like ours, at a distance from the scene of action, to take care that the subject is studied while there is yet time. On the spot, where no doubt the material is available, people are too much pre-occupied to notice the ultimate effect of their own personal activity. If we should, for example, set about exterminating the vermin of London houses (which, by the way, is above all things a most urgent question of rehousing), it is not from any Londoner nor even from our near neighbours in Cambridge, however interesting the minor horrors of war may be to their biologists, that any protest will be raised about the outrage which the extermination would entail upon the province of natural history.

I have looked through that interesting volume 'The Yearbook of the Universities of the Empire 1914' to see whether the other Universities of this country and the Empire had a notably extended or different range of subjects. The differences are mostly differences in name or in the differentiation of medical and theological subjects. It is interesting to note the gradual formation of University teaching in new lands. It seems to begin with medicine and theology, law, engineering, architecture, commerce, and banking; and next to take in our old college friends mathematics, classics, and natural sciences, but it seldom shows any particular characteristics of local scholarship or specialised learning; but in the older institutions there are some suggestive subjects as Assyrian and Babylonian archæology, classical archæology, African languages (Swahili and Bantu), Irish language and literature, Dutch language and literature, Japanese, Portuguese, Scandinavian languages and Thibetan, phonetics, library science, ancient Indian history and culture, colonial history, Irish history, Scots history, civic design and civic law, scholastic philosophy, Zend philosophy, rhetoric and oratory, geodesies, acoustics, meteorology, and epidemiology in various forms.

Among the subjects which I have noticed in other connections as not represented by name in any of the Universities of the Empire, but still claiming attention of those who would help to make the facilities for education complete, there are in the first place the history of the various arts and sciences, and of medicine, for which some provision has recently been made at Oxford under Dr. Singer; oceanography, which, through the generosity of Professor Herdman, has now obtained a footing in Liverpool; geodynamics, for which Cambridge wishes to make provision, historical geography and exploration; Malay and Polynesian languages and antiquities, aerodynamics, meteorological optics, now neglected in this country; terrestrial magnetism, seismology, climatology (past and present) particularly of the Empire; illumination and photography, metrology, the science of precision, British archæology and dialects; and perhaps the technical subjects of radio-telegraphy, ballistics, and ventilation. These are subjects with which alone a fully equipped University is competent adequately to deal, and the country is ill-provided until the educational authorities co-operate to supply between them what is needed. To secure this object, I am not at all convinced that State aid is the only possibility. The pious benefactor is no more extinct than he was in the days of Henry VIII. and Queen Elizabeth, but while the Universities and their Colleges speak with two voices and leave us uncertain as to their ideals, it is impossible that he should not be discouraged.

The views which I have expressed were formulated and in great part in manuscript while the war was still raging, and now we have celebrated the conclusion of peace. With the signing of the armistice came the demand for an actual address this year. Never in my experience have circumstances been so tragic as those which supervened. The stimulating drama of the war in which good strove with evil gave place to the new conflicts which have the characteristics of real tragedy. In the early part of the new year the hope that the sacrifices of the war would secure an immediate peace was blasted with disappointment. The whole connective tissue of civilisation seemed to be destroyed. The representatives of many peoples great and small assembled at Paris to make peace had first to find some *modus vivendi* for the future, but after a foretaste of a league of nations we found ourselves in a welter of jealousies, animosities, and struggles at home and abroad. Thousands were threatened with distress or with misery by the withholding of the necessaries of civilised life in order to secure the comfort of classes who regarded them as rivals and not comrades in the struggle for existence; the hard-earned savings of industrious lives vanished in taxes to be scattered broadcast as largesse by victorious politicians or grabbed by ruthless profiteers. Food and fuel were obtainable under the strictest limitations and under conditions apparently designed to be nearly intolerable; the aged and infirm were bereft of all the kindly offices that carry the sacred name of service; teachers abandoned their schools in order to settle a dispute about salaries.

We had just learned in the great school of experience that united self-sacrifice, and nothing short of it, could and did secure a victory over the powers of evil; and thereupon the whole world seemed obsessed with the idea that, the war being over, the time for sacrifice was done with; we could almost hear the many-voiced assertions of nations, of unions, of commercial associations, and of men and women generally, that as their sons and brothers had made the great sacrifice never again could they be expected to make another in this world. The elements themselves seemed to play their part in prolonging and deepening the gloom, and, as if impatient of the natural order, kept the world dead, cold, and miserable, far beyond the limits of an ordinary winter —in those circumstances, doleful beyond expression, what could be said about education. What ideals of education had led us to such a state of chaotic conflict of wills. It seemed impossible that mankind could ever recover and resume its sane and wholesome life of reciprocal give-and-take.

And in the midst of the gloom came a glimpse of Easter sunshine, and once more we heard the Easter words which have been the first audible sentence of many a mournful scene, 'I am the Resurrection and the Life.' What do they mean for us who have to try to live in this torn and distracted world? 'There will be no reconstruction and there can be no wholesome life for us or for anybody else without the spirit of self-sacrifice.' If the world takes the facile

view that self-sacrifice was over and done with when the last shot was fired at Mons, we are lost. We knew well enough that, whatever we may have done at home, without the sacrifice of our brothers at the Front and on the seas, we should have perished. And after that have we to learn the law of life, that we in our turn must go on bearing our part?

It is so obviously true. Look where you will, life is based on sacrifice for some ideal of duty. If each of us does no more than is required for our immediate necessities we cannot live. That is a commonplace of individual life, but in large measure we seem to forget it or ignore it in a corporate capacity. People will permit, as corporations or as a nation, inhumanities of which each individual would be ashamed. The Hebrews have given us a decalogue for individuals which at least satisfies the moral sense of the world. If it were not given by inspiration it must have been supplied by the simplest process of inductive reasoning. Without it social life is not possible. The sense of duty to our higher selves and our neighbours is our only sure guide. But now we want a decalogue for unions and corporations, for combines and nations.

To satisfy this imperative want we depend upon education. And therefore, by a simple generalisation, the educational corporations ought to show us the ideals of the principles and practice of a new code of conduct. And that is so because, at least in education and educational affairs, self-sacrifice must be obvious if there is to be real educational life. No teacher can ever teach anybody anything worth having who does not carry the signs of sacrifice in his teaching.

No body of teachers and no institution can really make a living education unless they are animated by that spirit. The ideals of education are not salaries and can never be attained by striking. I admit that when you are dealing with corporations the language is difficult. I do not quite know what a self-sacrificing county council would be, but I am perfectly certain that there can be no true social life which is based entirely upon the principle of inexorable contracts and has no room for humanity, for the give-and-take of self-sacrifice.

But all this must be, not for vanity, but for an ideal of duty that commands acceptance as true. Effective self-sacrifice does not mean non-resistance at all times and in all circumstances. In a conflict of ideals, as we have learned from the war, the most effective form of self-sacrifice may be to put one's self in a position to kill as many of the enemy as one can. And, in so far as the ideals have truth and vitality, they will evoke true loyalty. Consequently for all educational institutions the most important consideration is that they should manifest their ideals to be such as evoke from each the sacrifices which make for ordered life.

As one passes in review our own educational institutions one may judge of their ideals by their results. Judging in that way and looking at the education of our Public Schools we may fairly say that the social or ethical ideal is splendid. It expresses the principle of excellence which I take to mean success in fair competition. It is no doubt Hellenic rather than Christian, it is based upon the literature of the ancient Greeks, and has still strength enough to call forth the most devoted self-sacrifice. In the Universities also the same ideal is quite easily recognised. There, if anywhere, you can see the worship of success in fair competition developed into a real religion. For a long time I have thought that we should be much nearer understanding our real position in these things if we could persuade the classical scholars to do for Greek religion what the compilers and translators of the Bible did for the Hebrew. That is to collect together in the best available translation the literature of the Greeks which formed the basis of their guides to conduct. The appropriate contents of such a collection were sketched out by Dr. James Adam, a College colleague of mine at Cambridge, whose untimely death is still deplored, in his Gifford lectures on the Religion of the Greeks. With him the subject was a source of unbounded enthusiasm, and his lectures are a series of sermons on the testament of the Greeks. But we ordinary readers, unlearned in the Greek literature, are in the position of those who are offered sermons on the Old Testament instead of the Old Testament itself. If you imagine where we should stand if the Old Testament were denied to us except in the original Hebrew, you will understand the position the vast majority

of us must occupy with regard to Greek ethics, which are in fact the ethics of our ruling classes in the old sense. Therefore I use this opportunity to beg those who are enthusiastic for Hellenistic studies to give us such a testament. I feel sure it will enable us to understand the ideals of the Public Schools and Universities and throw an entirely new light upon the supposed conflict of classical and scientific studies, which is possibly only another phase of the other perennial dispute about religious education.

The ethical ideals of our schools and Universities are clear, excellent in themselves, and appreciated everywhere. They manifestly excite enthusiasm and develop the spirit of self-sacrifice for their maintenance. But what of the intellectual ideals? The subject is important because the cultivation of the intellect is the avowed purpose of academic institutions, and is the part of education which is necessary for carrying on the world's work. Looking at the actual practice of the Universities we can see that the intellectual ideals are obscured, confused, and enfeebled by the very process of competition between Colleges which is so eminently successful in developing the ethical spirit.

But the opportunity for strengthening and clearing our intellectual ideals is now. It may require some sacrifice of prejudices and traditions as between Colleges and the University, but the reward will certainly be great.

I suppose that a century ago the character of any distinguished educationalist would be summed up in the words 'He spared not the rod'; and to-day perhaps the highest praise is expressed by saying that 'He spared neither the ratepayer nor the taxpayer,' but even that is not enough. Money without motive power does not make education. We may reserve our highest praise for those educational establishments of which it may be said that in the pursuit of a true ideal they spared 'neither their prejudices nor their inherited privileges.' It may sound sacrilegious, but it must be said—the Portia of our dreams will not become the Alma Mater that the nation needs if she can never be obtained except after the manner of her father's will.

APPENDIX.

TABLE OF SUBJECTS OF LECTURES AND THE NUMBER OF PROFESSORS AND TEACHERS THEREIN IN THE UNIVERSITY AND COLLEGES OF CAMBRIDGE.

(*Taken from the Cambridge University Calendar*, 1918.)

Degrees and Diplomas	Subjects	University Teachers			
		Professors and Readers	University Lecturers and University Teachers	Total (University)	College Teachers
D.D., B.D., M.A. Certificate	DIVINITY	5	1	6	17
LL.D., LL.B., M.A.	LAW (including International Law)	3	1	4	10
	Indian Law	—	1	1	—
M.D., M.B., M.S., Ch.B.	MEDICINE AND SURGERY—				
	Physic and Medicine	2	2	4	—
	Vaccination	—	1	1	—
	Anatomy	1	8	9	—
	Surgery	1	1	2	—
	Pathology	1	3	4	—
	Medical Chemistry	—	1	1	—
	Medical Jurisprudence	—	1	1	—
	Medical Entomology	—	1	1	—
	Pharmacology	—	1	1	—
Diploma	Tropical Medicine & Hygiene	—	—	—	—
	Carried forward	13	22	35	27

TABLE OF SUBJECTS OF LECTURES, ETC.—(*continued*).

Degrees and Diplomas	Subjects	University Teachers			
		Professors and Readers	University Lecturers and University Teachers	Total (University)	College Teachers
	Brought forward.	13	22	35	27
Diploma	PUBLIC HEALTH—				
	Hygiene	—	1	1	—
	Chemistry of Hygiene	—	1	1	—
Sc.D., M.A.	PHILOSOPHY—				
	Moral Sciences—				
	Philosophy of Religion	—	1	1	—
	Moral Philosophy	1	—	1	—
	Mental Philosophy	1	—	1	—
	Psychology	—	3	3	—
Diploma	Psychological Medicine	—	—	—	—
	Mathematics and Natural Philosophy—				
	Mathematics	2	6	8	30
	Astronomy	2	—	2	—
	Statistics	—	1	1	—
	NATURAL SCIENCES	—	—	—	18
	Physical Sciences—				
	Experimental Physics	1	5	6	1
	Chemistry	2	7	9	—
	Mineralogy	1	1	2	—
	Metallurgy	1	—	1	—
	Astrophysics	1	1	2	—
	Geology	1	5	6	1
Diploma	Geography	—	3	3	—
	Biological Sciences—	1	2	3	2
	Botany	2	5	7	1
	Physiology	1	7	8	2
	Zoology	2	6	8	1
	Biochemistry	1	—	1	—
	Anthropology	—	1	1	—
	Genetics	1	—	1	—
	LETTERS—				
	Classical Studies—				
	Classics	2	—	2	33
	Comparative Philology	1	—	1	—
	Paleography	1	—	1	—
	Greek	1	—	1	—
	Latin	1	—	1	—
	Ancient History	1	—	1	—
	Archæology	2	—	2	—
	Ethnology	1	—	1	—
	English—				
	Anglo-Saxon	1	—	1	—
	English Literature	1	1	2	2
	English	—	1	1	—
	Modern and Mediæval Languages	—	—	5	—
	German	1	—	1	—
	Carried forward	47	80	132	118

TABLE OF SUBJECTS OF LECTURES, ETC.—(*continued*).

Degrees and Diplomas	Subjects	University Teachers			
		Professors and Readers	University Lecturers and University Teachers	Total (University)	College Teachers
	Brought forward	47	80	132	118
	Romance	1	—	1	—
	French	—	—	—	—
	Russian	—	1	1	1
	Italian	—	1	1	—
	Spanish	—	1	1	—
	Modern Greek	—	—	—	1
	Celtic	—	—	—	1
Diploma	*Oriental Languages*—				
	Hebrew	2	1	3	5
	Arabic and Turkish	2	1	3	—
	Chinese	1	—	1	—
	Persian	—	2	2	—
	Indian Languages—				
	Sanskrit	1	1	2	—
	Hindustani	—	1	1	—
	Bengali	—	1	1	—
	Marathi	—	1	1	—
	Burmese	—	1	1	—
	Talmudic	—	1	1	—
	Bibliography	1	—	1	—
	HISTORY AND ECONOMICS	2	—	2	23
	Ecclesiastical History	1	—	1	—
	Indian History	—	1	1	—
	Military History	—	—	—	1
	Political Economy	1	2	3	5
Mus.Doc., Mus.Bac.	MUSIC	1	2	3	3
	TECHNICS—				
M.A.	Engineering	2	4	6	5
Diploma	Mining Engineering	—	—	—	—
Diploma	Agriculture	3	2	5	—
Diploma	Forestry	1	2	3	—
Certificate	Education	—	1	1	—
	ART AND ARCHITECTURE—				
Diploma	Fine Art	1	—	1	—
	Lectureships with no Subjects assigned	—	1	1	6
	Number of Teachers	67	108	176	145
	Number of Subjects	—	—	(73)	(23)

Discussion upon the Teaching of English.

Report on the Free-place System.

WEDNESDAY, SEPTEMBER 10.

The following Report was read, and Discussions took place :—

1. *Report on Museums.*—See Reports, p. 125.

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2. *Discussion upon the Method and Substance of Science Teaching*, opened by Professor H. E. ARMSTRONG, *F.R.S.* In the course of the discussion the following Paper was read :—

Substance and Method of Science Teaching. By Sir RICHARD GREGORY.

Science teaching in boys' Secondary Schools usually begins with Nature Study and proceeds to Elementary Physical Measurements. Elementary Heat and Elementary Chemistry are then taken, followed by Systematic Chemistry and, in the Public Schools, by General Physics. Light, Electricity, Sound and Biology are studied by relatively few boys, and Astronomy, Geology, Natural History and Archæology are almost unknown as school subjects.

In most girls' schools, as in boys', Nature Study represents the early stage of instruction in science, and Botany is the main subject taught, but Physics, Chemistry, Hygiene and Domestic Science are also started at an early age. The Physics and Chemistry in some girls' schools are taught on the same lines as in boys'; in others, these subjects are used as introductions to a course of Domestic Science and Hygiene, or of Botany. A course of Experimental Science which embodies the rudiments of both Physics and Chemistry sometimes precedes the formal teaching of these separate branches of science in both girls' and boys' schools, and may be carried through the curricula.

As regards the substance of science teaching in general, it may be said, therefore, that little attempt is made to provide pupils with courses which will give them an intelligent interest in the things around them, whether natural or artificial. The weak points of the instruction are insufficient attention to the broader aspects of natural knowledge and to scientific discovery and invention as human achievements, and failure to connect school work with the big applications of science by which mankind is continually benefiting. There is indeed a tendency, as instruction in science proceeds in the school, for it to become detached from the facts and affairs of life, by which alone stimulus and interest can be secured.

The chief reason for the narrow character of most science courses in schools is the small amount of time available and the demands made upon it in recent years by laboratory and other practical work. The substance of instruction has suffered from the concentration upon method, and the right adjustment of the conflicting claims of the two in a truly educational course has yet to be found.

Experimental work is essential for acquiring an acquaintance with the nature and meaning of scientific inquiry in the field of natural knowledge, and its highest type is reached when the motive and purpose are part of the pupil's own understanding, as it is assumed to be in heuristic teaching. Exigencies of the time-table, however, do not permit of much individual pondering upon problems and their scientific examination; and organised drill in laboratory exercises illustrating fundamental properties and principles constitutes the experimental work undertaken. Most of the time allotted to science in schools is taken up with this practical work, and what remains is devoted to the elucidation of the subjects involved. The scope and rate of study are determined by laboratory work, with the consequence that the outlook attained at the end of a school course is very much restricted instead of being broad and catholic.

One way to avoid this unsatisfactory end is to separate the training in experimental method from the substance of descriptive lessons and reading. Let a broad general course of science be followed independently of the intensive laboratory work in particular branches, designed solely to create and foster the

spirit of experimental inquiry by which all scientific progress is secured. In this way it should be possible, even with the present limitations of time, to provide training in method, as well as wide knowledge of substance, of science. Before any reform of this character is possible, however, schools and examining bodies must revise their syllabuses so that the school course can be complete in itself and not, as seems generally to be assumed, merely preliminary work for pupils who intend to proceed to science degrees in universities.

In the course of the above discussion the Teaching of Botany was dealt with in joint session with Section K (see p. 336).

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3. *Joint Discussion with Section F upon Business in relation to Education*, opened by the following Paper:—

Business in relation to Education.

By Sir HERBERT E. MORGAN.[1]

Business and manufacture always include three elements—capital, labour, direction. Importance of the directing, educated element in business: each additional directing brain provides work for number of additional employees, reduces unemployment, increases output, furthers national trade, uses capital to best advantage.

Twofold theme of paper. (*a*) More and wider education for business men present and prospective. (*b*) More of the liberally educated class to be attracted to and prepared for business.

(*a*) Men little educated outside limits of business apt to be narrow. Narrowness limits conception of business possibilities, hampers initiative. Also liable to cause friction with labour: does not recognise needs and legitimate aspirations of labour, necessity of adaptation to changed conditions of life.

Need for better commercial education of men and boys proposing to enter business. Shorthand, typewriting, book-keeping not enough, except for quite subordinate grades. Hitherto no method or standard of training for business as for law or medicine. London University proposal for Degrees in Commerce designed to change this. Importance to business men of foreign languages, geography, history, economics, all studied with special reference to commerce. Outline of proposed course. Applicable both to those about to enter business and to existing business men. Business education will render available large supplies of brain-power just demobilised and at present lying idle.

Business formerly looked down upon by University and public-school men. Wrong ideas of business; not presented as attractively as learned professions: regarded as simply sordid money-getting; national and Imperial aspects not emphasised. Business achievements in the past: the flag follows trade. Possibilities in future. Former prejudice by employers against University type: regarded as wasters and unfitted, by their training, for business. Both prejudices already disappearing before war: war has hastened the process. Men of this type now ready to turn to anything: shortage of personnel has led business men to make experiments which have proved value of University type.

Need for business knowledge before offering services. Business training should be in addition to, not substituted for, regular University course. Commercial degrees needed at Oxford and Cambridge as at London University, so as to graft sound business training on to admitted advantages of the older Universities. Appeal from them for Government grants offers opportunity to make provision for this.

Summary.—Great need of the day is largely increased production. This is impossible without skilled direction. Educated men needed for direction, men educated in the right way, with technical training added to sound general knowledge and broad views. Boundless possibilities in business for both self-

[1] See *Ways and Means*, 1919.

advancement and national and social service. Fascination of business. Chance for every young business man to win unique position for himself, emulate the great achievements of the commercial explorers in days gone by, place himself on a level with merchant princes of to-day. No limitations : no ruts : man's fortune is in his own hands.

THURSDAY, SEPTEMBER 11.

The following Discussion took place, and Papers were read :—

1. *Discussion upon Continuation Schools*, opened by Sir ROBERT BLAIR.

The following Papers were read :—

Continuation Schools: The Problem of Works Schools. *By* Dr. A. P. M. FLEMING.

The Education Act of 1918 renders possible that intimate association between education and industrial life that is so desirable, having regard to the fact that national life is dependent on industry.

(1) *The* 1918 *Education Act (England) in Relation to Industry.*

So far as industry is concerned, the following are the main requirements of the Education Act, which become operative twelve months after the appointed day :

(*a*) The raising of the school-leaving age to fourteen.
(*b*) Attendance at continuation classes during the daytime.

A dual period is covered.

(1) As children attain the age of fourteen they are required to attend for eight hours per week until the age of sixteen. This will continue for a period of six years from the date the Act comes into operation.

(2) After this period the age of continuation-school attendance is extended to eighteen.

The Act does not apply :

(1) To young persons over fourteen years of age on the appointed day, except at the request of the young person.
(2) To University matriculants or those who possess equivalent qualifications.
(3) To young persons who are receiving efficient full-time or part-time instruction in some other manner. Works schools are recognised under this ruling, provided they are conducted to the satisfaction of the Local Education Authority.

(2) *History of Works Schools.*

Prior to the Technical Instruction Act, 1891, several enlightened employers provided technical instruction in classes on their own premises, but the majority of the attempts were abandoned when technical schools were established by Local Education Authorities.

While the technical schools provided admirable and necessary facilities for the training of boys capable of rising to the higher positions in industry, they were not well suited to the needs of the large majority of boys from the primary schools who would become manual workers. To meet this latter need several works schools in various industries were established.

With the passing of the 1918 Education Act the scope of 'works' schools is substantially extended. The youth's interest in his work, and his association with industry, is desirable as the basis of a comprehensive system of education culminating in the complete development of the character of the individual adolescent.

(3) *Criticism of Works Schools.*

Works schools are criticised on the ground that they have a limited application—only being possible in a large works—that no desirable form of education can be administered in the environment of a works, and that the provision of education is a function, not of employers, but of the State.

(4) *The Advantages of a Works School.*

Properly conducted works schools possess many educational advantages, some of the more important of which may be referred to as follows :

1. A close correlation can be established and maintained between the school work of the adolescent and his practical training in the works, each of which favourably reacts upon the other.

2. Teachers who are familiar with works life are most capable of taking a more intelligent and sympathetic interest in the progress of the boy, both in the school and in the works, and can effectively introduce into the class-room the spirit required in continuation-school teaching.

Other features of the works school referred to below have an important educational value.

(5) *Works Schools as a Factor in Industrial Development.*

Through the medium of works schools certain developments in industry are greatly facilitated, and the social and economic advantages accruing from these even outweigh their educational advantages.

1. *Selection for employment and promotion of workers.*—Latent ability can be discerned, and its utilisation effected, only by teachers who are interested in and closely identified with the youths in the works.

2. *Training of Workers.*—The systematic training of workers is a matter of paramount importance in industrial development, and can be facilitated through the medium of a works school.

3. *Industrial Harmony.*—The close contact between juvenile workers and the teaching staff of the works school ultimately ensures harmonious relations between management and workers.

4. *Citizenship.*—It is of growing importance that adolescents should receive some training in the practice of civic and economic principles, having regard to the increasing opportunities for workers to share in the responsibilities of industrial life.

Continuation Schools: The Problem of Urban Schools.

By C. A. Buckmaster, *M.A.*

Continuation Schools: The Problem in Rural Districts.

By G. F. Daniell, *B.Sc.*

Successful development of continuation schools in rural districts will add greatly to national well-being. Such development is hindered by difficulties other than those in urban districts.

(1) *Scattered Population.*—Distance between villages which individually are of insufficient population to provide an economic number of young persons affects every arrangement—*e.g.*, choice of site, staffing, periods of opening, collaboration with voluntary associations for social service. If young persons cannot be compelled to attend unless the school is within two miles of their homes or transport is provided, every available means of transport—bicycle, country carts, motors (omnibus, lorry, agrimotor, or other) must be discovered and utilised.

(2) *Educational retardation.*—Speaking generally, continued education is in a backward state. Even the extension of full-time schooling to 14 *plus* will produce grumbling, although organised opposition is not to be feared. Every village enthusiast for education should receive encouragement by visits from L.E.A. headquarters staff, by sympathetic correspondence, and by giving finan-

cial support to classes which would rightly be considered too small in towns. Conferences with parents and employers are even more necessary in the country than in the town.

(3) *Dark roads and lanes.*—Throughout the year in the towns, and during the summer time in the country, it is not unlikely that the period 2 P.M. to 6 P.M. or 6.30 P.M. will be the most valuable. But in country districts young persons should not travel in the dark more than can be avoided. Schools should be as near their homes as possible, even though this will involve modest housing and equipment, with teachers to a certain extent peripatetic. It would be wasteful to arrange for less than a full day of seven or eight hours. This should include a recreative period.

(4) *Lack of rural employment.*—Adapting the maxim of Pestalozzi, we must 'study the young person.' The adolescent is looking forward to the occupations of manhood and womanhood, and on purely educational grounds part of the instruction should be vocational in a broad way. But the majority of the young persons will find employment not in the country but in the towns, and they know it. Those already employed in the towns may find their continuation school near their work rather than near their home, and thus further reduce the numbers of the village continuation school. It would be well if the lads attended a voluntary evening class in the village. The girls will presumably be housed by their town employers, and the urban continuation schools will provide for them.

(5) *Staffing.*—There should be a staff of full-time teachers (of whom many must be cyclists, in some districts motor-cyclists), and the services of social workers in the neighbourhood should be invited. To recruit teachers, one must be able to say with some precision when posts will be open, what are the total hours of work and how they are distributed, the pay and conditions of service. It is much more difficult to answer the questions in the case of rural work, but they must be answered before men and women will come forward to be trained.

Various possibilities.—Relations with village clubs and institutes should be close; a playing-field and meeting-hall used in common may prove durable links. A good site of five or six acres should be acquired (a larger site would be better) for recreation ground and buildings, the site being regarded as permanent, the buildings should nevertheless be temporary or semi-permanent. Part of the buildings may be reserved for educational, part for recreative purposes, and part may serve both purposes. One of the recreation rooms may be reserved for each sex. Local considerations will determine whether school one day per week for forty weeks or a seasonal arrangement of attendance is preferable. In the latter case the farmers must be prepared to pay wages during the school sessions. Periods intermediate between one day per week for forty weeks and full time for eight weeks are, of course, possible. If there are three terms in a year in the elementary school there will be six batches of fresh entries in the two years of the present compulsory continuation course. Syllabuses of instruction may be in some subjects cyclic rather than consecutive, so that entrants may begin a branch of a subject in the same class with those who have been from one to five terms in the school. It is hoped that careful consideration will be given to the possibilities of seasonal boarding-school arrangements, which would meet the difficulties of thinly populated areas, while possessing such high educational advantages as to compensate the large initial outlay involved. There is need for much thought, experiment, and pooling of experience, and as a contribution which may be helpful I submit a report on the Toy's Hill Residential Farm School held during the first four weeks of 1914.

The Toy's Hill Experiment.—The course was voluntary, vocational, and no grant was received from the Board of Education. Twenty boys attended. Expenditure, 187*l.* 11*s.* 9*d.*; receipts: fees, 30*l.*; other receipts, 2*l.* 9*s.* 6*d.* During the succeeding five years there has been evidence of the benefits derived from the course, that of farmer-employers being very favourable. In any course now proposed the duration would be eight or nine weeks, and a considerable amount of non-vocational instruction would be given.

Continuation Schools: The Workers' Educational Association. By J. S. Rainer.

The policy of the Workers' Educational Association in regard to Continuation Schools comprises opposition to the recognition of 'works' schools.' The employer should be represented on advisory committees, but should have no personal control. Existing works' schools could be absorbed for the time being into the continuation system. The W.E.A. working men distrust the employing interest, as it is almost exclusively personal and mercenary. The size of classes shall not exceed 25; provision for medical and dental treatment, as in the elementary schools; adequate provision for physical training; subjects of study to be correlated with the interests of the pupils, but not determined merely by trade needs. The curriculum must aim at general culture, for 'the life is more than meat and the body than raiment.'

Continuation Schools. Remarks by the Rt. Hon. the Earl of Malmesbury, *M.A., D.L., J.P.*

(1) *Economy.*—The education problem in its present phase had been introduced at a moment when there was the most serious need for the greatest national economy, and it was almost impossible to see how the Chancellor of the Exchequer and the local authorities would be able to meet it. The author considered that in return for this expenditure full consideration should be given to what could properly be termed a great national asset—namely, the spending of money to the fullest advantage on boys and girls of exceptional and admitted ability.

(2) *Individualism.*—Too little attention was paid in these days to the individual character of the child. Educationalists had fallen into the great error of placing the average intelligence on too high a basis, and imagining that anyone could be turned into a scholar or scientist if sufficient money was spent on him. This was not true; environment might have much to do with the moulding of character. It was not everything; the natural bent would assert itself. For example, many people born in the most favourable intellectual environment could never rise to the fulness of their opportunities, and this applied to all classes of society. The educational system ought to be dealt with on the principle of a triangle with a very broad base for a sound elementary education, but gradually through a series of layers narrowing down by careful selection to the survival of the fittest.

(3) *Materialism and Spiritualism.*—It was difficult to say where materialism should stop and spiritualism begin in our educational system. Materialism, when kept within its proper bounds, was a national asset not to be lightly disregarded.

(4) *Conclusion.*—It could not be denied that in the interest of the individual, as well as of the State, each boy and girl should be educated in such a way as would conduce to the carrying on of the world's work, and a clear distinction should be made between those who would be much more happy and successful as manual workers and those whose natural bent was of a high intellectual order.

In regard to Continuation Schools, a scheme far more satisfactory, and involving much less expenditure of public funds, would be the establishment of Secondary School Centres, to which by a process of careful elimination only the more intelligent brains would find their way, and thence would reach the top of the educational ladder.

The so-called 'intellectual' was not usually in the end the most useful citizen; man's individual nature must ultimately triumph over the conventionalism of a superficial educational system. Patriotism, personal obligations, and good manners were almost wholly absent from our modern curriculum.

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2. *Consideration of Proposals for promoting interchange of Students between British and Scandinavian Countries.* *By* Dr. VINCENT NÆSER.

3. *Educational Value of the Cinema.* *By* Sir RICHARD GREGORY.

FRIDAY, SEPTEMBER 12.

The following Discussions took place :—

1. *Discussion upon Training in Citizenship*, in which the following took part :—

The Rt. Rev. J. E. C. WELLDON, D.D. : Everybody now is an educationist. There is everywhere a demand for education—for an education such as will in its results justify an annual expenditure of more than £25,000,000, and a largely increased expenditure in the near future.

The teaching profession, if it aims unitedly at an object, can attain that object. It can create a nation of Huns. It can create a nation of heroes. But the teaching profession seems to have lost something of its old attractiveness, for not only are the most distinguished of the undergraduates at Oxford and Cambridge less willing than they were 50, and even 25, years ago to become masters in the public schools, but it is stated that double the number of candidates for masterships and mistress-ships are needed to-day in the elementary schools of London and the great provincial centres. The law of citizenship as governing education prescribes that the teaching given to children must be such as shall make the best possible use of the years allotted to education. In elementary schools the proverbial three R.'s were once regarded as constituting the sum of education. Men of business used to tell me in Manchester that they would gladly sacrifice the so-called accomplishments of their clerks and typists for a sure basis of elementary knowledge.

It is practically certain that in the future not only boys and girls, but men and women, will be educated together, irrespective of social standing; the universities will be more and more thrown open to poor students. Something must be done by co-operation or co-partnership to create a fellow-feeling between capital and labour. The schools—and above all the elementary schools—must teach an enlightened patriotism. The children, who will so soon be the adult enfranchised citizens, must be made to understand the dignity, as well as the history, of the Empire.

There is yet a final lesson which the schools must teach in the interest of citizenship. It is the lesson of civic unity. Children whose parents possessed divergent views, not only in politics but religion, must so far as possible be educated together.

Sir ROBERT BADEN-POWELL, *K.C.B., LL.D.*

The need of out-of-school training and environment, as auxiliary to education, for producing efficient and human citizens.

This applies to girls equally with boys, their rapid social evolution having outstripped their education.

The main need for such training seems to lie in the direction of

Character and Intelligence; Health and Physical Development; Handcraft and Technical Skill; Service for the Community; Happiness through higher ideals.

The method of such training should be preferably through education rather than through instruction; through active desire from within to learn and to express rather than from passive reception of ideas from without on the part of the pupil.

These points are met in what is known as 'Scouting,' a training which has evolved itself from the child's point of view rather than that of the teacher.

Woodcraft with Nature-lore is its key-activity.

The training is adapted to the psychological stages of the adolescent life in the Wolf Cubs, Scouts, and Rovers.

Individuality is developed and then harnessed for the betterment of the community.

2. *Discussion upon Fundamental Principles in Education, opened by* Professor A. N. WHITEHEAD, *F.R.S.*:—

All education is the development of genius. Genius is the divine instinct for creation, incident throughout life, a certain quality of first-handedness accompanying and directing activity. An education mainly devoted to the development of genius is the best education for eliciting common sense. The three factors of genius are the habit of action, the vivid imagination, and the discipline of judgment. Criticism is the antagonist of genius, though it is essential for the discipline of judgment. The function of criticism is the education of genius by the aid of knowledge.

The acquisition of knowledge is the ultimate substratum of education. Knowledge and genius are the twin factors of effective personality, and the true ultimate problem before the educator is how to impart knowledge so as to stimulate genius.

A curriculum should start with obvious relevancy, and should progressively widen as the field of relevancy expands—the subject-matter of early education should issue quickly in securing some definite acquirement. The stimulus of success is essential for any broad effectiveness of culture.

Literary education is of overwhelming importance. Language is essential. The study of language has importance, relevancy, and the certainty of a large measure of success. You can only spoil its effect by one procedure—namely, by teaching a language which the pupils can never acquire, will never want to use, and which is the vehicle of a literature whose relevancy is only immediately obvious to a mature mind. You must not go on to a dead language until a modern language has gripped the imagination. Classical learning is the superstructure of a literary education, not the foundation. Classical learning has had its chance with the well-to-do class, and has failed—failed to impress on them that learning should mould life, a failure which originates in a lack of relevancy in the subject-matter of education. The technical triumphs of science in war and in industry have startled English thought back into sanity, for it is sanity to believe in the importance of knowledge. Learning is not advocated for the sake of mere utility, but utility for the sake of learning. Knowledge should proceed from the concrete to the abstract. General education, the basis of culture, should be compact of material which will enter into the habitual lives of its recipients, a doctrine which applies alike to language, literature, history, natural science, and to mathematics. Beyond this general education every educated person should push on to a specialism dominated by finer theory and by subtler ideas—for one it may be Greek, another scientific theory, for another mathematics. There can be no complete education without specialism, but classical specialism is not general culture.

It is the demand of genius that it lives its own life in its own way. It is the function of education to supply criticism and knowledge.

The one fundamental principle of education—that the pupils are alive, and not mere portmanteaus to be neatly packed.

Fundamental Principles of Education; The Literary Aspect of the Question. By F. S. PRESTON, *M.A.*

The word 'humanistic' is purposely avoided as being applicable to any subject studied for its own sake. The object of a general education is not merely to acquire knowledge, nor to provide a man with a commercial asset, still less to bestow the label 'qualified' as the result of an examination test, but to produce

the trained mind essential to a full member of a civilised community. (Examinations, except as a test of individual progress, are a serious blot on education.)

The course of linguistic studies needs no defence, and the claims of scientific studies are duly recognised by educationalists. The interdependence of the two is confidently asserted.

There is the menace to a wide education from the Bolshevism of fanatics, who would destroy the old because it is old. Such extremists are injuring their own cause, and incidentally display an ignorance of the capacity and bent of the average boy. They are possibly deluded by the phenomenon of a primitive mechanical interest, which they mistake for a sincere scientific enthusiasm.

The present situation is critical for five reasons—the degenerate standard of modern British taste in literature and the theatre, the importance of the growth of 'Cosmopolitan' ideas of brotherhood, the increase in the leisure time now available to the less educated population, the demands of the new Education Acts for extending the educational facilities of the majority, the general ignorance of economics intensified by the complete ignorance of history.

Modern secondary education exhibits a reasonable division of the curriculum between scientific and other studies. There is a danger in one-sided specialisation: in particular, the battle against an exaggerated vocational training must be fought. A possible cause for present discontent is the starving of the spiritual life and the imagination. The highest education is association with great minds; through the medium of art and literature this is possible for all. Imagination and reason both must be developed: either is incomplete alone. Science cannot provide both for all, nor can all be 'scientifically' educated at first hand. A wise compromise is essential and desirable.

The writer is no linguistic fanatic nor desirous of 'subordinating progress and the future to the realm of ghosts and nursery tales.' From his own experience of the young mind he would emphasise the need of literary studies to develop the imaginative and moral faculties. Mankind will never be satisfied by an education limited to the finite or to demonstrable truths.

Fundamental Principles in Education: The Function of Examinations in Education. *By* Prof. MARCUS HARTOG, *M.A., D.Sc.*

The methods of pædagogics may be roughly classified into *Exposition, Study*—including set tasks, observation, and preparation by the pupil—and *Examination*, which is not merely the test of the two former, but possesses training virtues which are all its own.

Examinations may be oral or written; but, for the purposes of this paper, I shall limit the term to the written, where the pupil answers set questions unaided (and in the later stages in a limited time), and where the scripts are marked for merit—*sit venia verbo*—by the examiner, and in the earlier stages form the subject of a 'lesson on the scripts,' when they are commented upon by the teacher, and, it may be, by the class. Examinations fall naturally into three groups—*Class, Grading,* and *Selective*—for which some award is made, whether it be place, prize or appointment. Where these are made on the result of grading examinations, they acquire a selective character.

Class examinations begin as soon as the child has acquired some freedom of expression in writing, and are continued through not only his school life, but in many cases form part of academic teaching, from which the practice of the best coaches only differs in their more constant utilisation. Together with oral examinations they are the essential complement of exposition and study. The method is invaluable for the teacher, since in reading the scripts he is enabled to discover the weak points of his teaching and to amend them. To the pupil it affords training *in independent thought*, unaided by the help of the teacher, who can with difficulty restrain himself from helpful suggestions in an oral examination. He learns the value of *persistent concentration. Terseness and directness of expression he gains*, if only to avoid the tedious handiwork of handwriting. *Precision and clearness of expression* are insisted on by the teacher, who will never tolerate fluffiness or confusion of ideas. And *clearness of understanding* is needed, for answers wide of the mark—volunteered answers—are as worthless here as at any later stage.

The judicious teacher will insist on every answer being a complete *logical predication*, especially in the case of short answers: if a definition be asked for, the answer must contain a statement as to the application thereon. Thus if the question be 'Define the fulcrum of a lever,' the answer, 'The fixed point on which the lever turns,' must be recognised as absolutely worthless.

Where questions of wider range are set, the pupil is given the opportunity of acquiring both *literary form* and *symmetrical logical order*, of which the importance must be demonstrated by the teacher. *Composition* is thereby better taught than even by the classical method of 'Narration from memory.' Here I speak from the experience of five years' examining in botany under the Irish Intermediate Board. It is impossible that pupils, save of the most ungrateful nature, who have had proper training by the method of class examination should incur the oft-quoted censure of one great authority, who writes: 'That an examination candidate writes for a person who, in general, knows already what he has to say, *i.e.* the examiner . . . may be trained unwittingly to express himself obscurely and by allusion.' The candidate who does this damns his teacher, whether schoolmaster or coach: such modes of expression make for low scoring everywhere.

Grading examinations are invaluable for giving method to teaching and study and limiting its range in any given period to reasonable bounds. The brilliant teacher and the brilliant student are ever in danger of covering more ground than they can profitably survey. For the student who works alone the graded course of examinations affords one shield for perseverance which it would be stupid and Pharisaical to ignore. A man who studies 'to improve his mind' is liable to be assailed by the temptations to accept lower aims, obsessed by the jeers of his friends and family. But the pursuit of a University career gives his pursuit that business-like character that cannot fail to impress Mrs. Grundy. Herein lies the use of the 'Examining University.'

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3. *Discussion upon the Present Position of Private Schools.*

Section M.—AGRICULTURE.

President of the Section: Professor W. Somerville, D.Sc.

TUESDAY, SEPTEMBER 9.

The President delivered the following Address :—

Grass.

During the past four years—or since the ploughing programme began to take shape—grass land has been officially cold-shouldered in no small degree. The cause was obvious and the reasons were good. The result of compulsory and voluntary ploughing has been that whereas in 1914 the total area in Great Britain under temporary and permanent grass (hay and pasture) was practically 21½ million acres, it was barely 19½ million acres in 1918, a reduction, namely, of about 2 million acres. During the same period the arable area, other than temporary grass, increased from about 10½ million acres to 12½ million acres. In Ireland, during these years, the area under grass (permanent and temporary) fell from about 12½ million acres to less than 11¼ million acres. The United Kingdom at the present time comprises about 30½ million acres of permanent and temporary grass and 15½ million acres of land under crops other than grass and clover. This is over and above some 16 million acres of mountain land used for grazing.

It is far from my intention to attempt to maintain that grass land is, as compared with tillage, defensible from the point of view of national economy. It has been proved conclusively by various writers, and by none more convincingly than by Sir Thomas Middleton, that in respect of nutritive output, and the utilisation of labour, and in its bearings on foreign exchange, arable cultivation is much more attractive than pastoral farming. It is my sincere hope that the Royal Commission now sitting will be able to formulate a policy, acceptable to the Government, which will result in the retention for tillage of at least all that the plough has gained during the war, and, in my view, it would be well for the country if a much larger area even than that could be wrested from the grazier. But for the moment the tendency is in the other direction, and under the stimulus of high wages, and increased costs generally, a certain amount of land has already been resown to grass, and preparations are being made for similarly dealing with an increased area next spring. It would, therefore, appear that under any circumstances that can be conceived the area of land under grass is likely to remain at a very high figure, and to be well worth the consideration of this Section of the British Association.

A considerable proportion of the grass land of this country is of so high a quality that any improvement, and certainly any economic improvement, is hard of accomplishment. Satisfactory as are the high-class pastures of this country, it by no means follows that there is nothing more to learn about them. Grazing practice is in general agreement that the productive capacity of these pastures is maintained by judicious stocking during the growing season, by the regular mowing of thistles and other coarse weeds, by the maintenance of the drains (if such exist), by the spreading of the droppings of cattle, by the avoidance of winter grazing (at least in the case of land liable to 'poach'), and, in many cases, by the consumption of a certain amount of cake, at least during the latter part of the season. On many of the high-class pastures no cake is used, so

that the annual drain of nitrogen and minerals in the form of animal increase must be balanced—if fertility is maintained unimpaired—by the nitrogen gained in various ways from the air, and by the weathering of inert mineral matter in the soil. As, however, 300 lb. of live weight 'fattening' increase per acre per annum—which may be assumed to be about the maximum production of high-class pasture—will contain only about 3 lb. of nitrogen and a similar amount of mineral matter, the natural agents will have no difficulty in replacing this loss. It would appear in fact that, but for the loss of plant food by drainage and denitrification, even a fattening pasture should go on improving, and this is the case so far as accumulated fertility is concerned, though not in respect of current or immediate animal production. On a pasture of naturally low quality, where leguminous herbage stimulated by phosphatic manuring is the main factor of value, it has been proved at Cockle Park that the addition of nitrogen either as artificial manure or in the form of cake residues has been positively injurious or has produced a result disappointingly small, and one would like to see this subject followed up experimentally in the case of naturally rich pastures where cake is freely used. One would like to study in detail the effects of phosphate and potash on such land, although where production is naturally so high it is unlikely that it can be materially and economically increased.

It is often very difficult to determine the factor or factors that go to the making of high-class pastures. Such pastures are to be found on most of the geological formations of this country; they are met with north, south, east, and west; and even altitude, within the limit of at least seven hundred feet, seems to have little effect. An immense amount of attention has been given to the botanical composition of the herbage of the more famous of the pastures of Britain. Notable in this connection is the work of Fream,[1] Carruthers,[2] Hall and Russell,[3] and Armstrong.[4] The methods employed varied to some extent with the investigator. Fream had turfs dug up and transferred to Downton, where they were planted in the garden, the herbage being subsequently clipped over and separated; Carruthers, Hall and Russell relied partly on enclosing representative areas and sampling the herbage when well grown, and partly on occular estimation; while Armstrong used a frame a foot square divided by transverse strings into 144 square inches. This was placed on the sward *in situ* and a note made of the percentage occurrence of the different species of plant. The result that emerges most conspicuously from these researches is that one may have a dozen pastures, which are about equal in feeding value, and yet which may vary widely in respect of botanical composition. Thus Fream found that in the case of forty-eight English and eight Irish pastures, each of which was the 'best' in the district selected, the Gramineæ might be as low as 11 per cent. and as high as 100 per cent.; Leguminosæ might be entirely absent or as high as 38 per cent.; while of miscellaneous herbage, most of which would be designated as 'weeds,' there might be none or up to 89 per cent. As regards individual genera and species, Fream found for instance, that Agrostis was almost always present and on five occasions was the most abundant plant; while *Holcus lanatus* gave an almost identical result. By a different method Carruthers arrived at a very similar conclusion. The latter also found that *Hordeum pratense* was the most abundant species on what is perhaps the finest grazing in England, namely, Pawlett Hams, near the mouth of the Parret in Somerset. This investigator even found that on one of the 'Famous Ancient Pastures of England' the predominant grasses were Fiorin and Hassock, and in this connection makes the

[1] W. Fream, 'The Herbage of Old Grass Lands,' *Jour. Roy. Agric. Soc. Engl.*, vol. xxiv., 2nd Series, p. 415; and 'The Herbage of Pastures,' *Jour. Roy. Agric. Soc. Engl.*, vol. i., 3rd Series, p. 359.

[2] W. Carruthers, 'The Composition of Some of the Famous Ancient Pastures of England,' *Jour. Roy. Agric. Soc. Engl.*, vol. i., 3rd Series, p. 751.

[3] A. D. Hall and E. J. Russell, 'On the Causes of the High Nutritive Value and Fertility of the Fatting Pastures of Romney Marsh and other Marshes in the S.E. of England,' *Jour. Agric. Science*, vol. iv., p. 339.

[4] S. F. Armstrong, 'The Botanical and Chemical Composition of the Herbage of Pastures and Meadows,' *Jour. Agric. Science*, vol. ii., p. 283.

following remark, 'In this field the hassock-grass, which made up a large proportion of the pasture, was freely eaten, and the cattle were in good condition.'

In Hall and Russell's investigations Agrostis and Holcus might on occasion each exceed 20 per cent., and it is stated that 'Wherever *Holcus lanatus* occurs it is more abundant on the fatting fields.' Even miscellaneous herbage could bulk over 29 per cent. on a pasture so good that it could fatten five bullocks on four acres without cake. Armstrong found in a field representative of 'the richest type of old grazing land found in the Market Harborough district' that, amongst grasses, *Poa annua* came second (12·3 per cent.) in point of abundance; while in two meadows, also in Leicestershire, the one representative of 'the choicest meadow land of the neighbourhood,' and the other 'a meadow of above the average quality,' the grasses were 41·5 per cent. and 70·3 per cent. respectively, in the second case Agrostis amounting to 12·7 per cent. There will be general agreement in this audience that four of the grasses just mentioned, Fiorin, Yorkshire Fog, Squirrel Tail, and Hassock are accounted 'bad,' and yet it is hard to apply this term to plants which are the most abundant constituents of some of the finest pastures in England. While there is much that is disconcerting in these investigations, some facts do emerge with satisfactory consistency, (1) that the great majority of high-class pastures contain a large proportion of perennial ryegrass and white clover, (2) that crested dogstail is almost always present though rarely predominant, (3) that meadow fescue is practically negligible, and (4) that of the two Poas, pratensis and trivialis, the former is very rare, while the latter is very common.

The obvious deduction to be drawn from these investigations is that the quality of a permanent pasture is only in a minor degree determined by the relative abundance of its constituent plants, or, in the words of Hall and Russell, 'We can only conclude that the feeding value of a pasture is largely independent of the floral type.' Factors of much greater weight are depth and physical character of the soil, soil moisture and temperature, density of the herbage, and the natural or induced composition of the soil as regards plant food, and especially in respect of phosphoric acid.

That much seems to have been proved, but, such proof notwithstanding, I cannot think we are justified in going so far as Carruthers, when he says, 'The composition of the pastures shows the fallacy of seeking in natural pastures the standard for laying down arable land in permanent grass. The adoption of such a standard is to reverse the whole practice and principles of modern farming.'

It seems to me that the lesson that may be learned from a study of the old pastures of England is that we need not include in a seeds mixture for permanent purposes plants which never bulk to any considerable extent in old grass land, but that we should include all of those which are usually naturally abundant. Take, as an illustration, the case of perennial ryegrass. In the eighties of last century, when much interest was taken in the subject of the best way to lay down land to grass, an almost violent controversy arose over the desirability or otherwise of including perennial ryegrass in a seeds mixture for permanent pasture. The main opponents of ryegrass were Faunce de Laune and Carruthers, who would have excluded this species under all circumstances. The work of Lawes, published under the title 'The History of a Field newly laid down to permanent grass,' [5] also tells against ryegrass, though it is to be noted that the field in question, sown down in 1859, was mowed every year, and there is some reason to believe that this grass is more persistent in a pasture than in a meadow.[6] On the other hand, we have the evidence of a series of experiments laid down by myself in Huntingdonshire in 1900 and reported on in 1905 by Biffen [7] and Middleton,[8] which shows that under certain

[5] *Jour. Roy. Agric. Soc. Engl.* 1889, p. 1.

[6] R. G. Stapledon and T. J. Jenkin, 'Pasture Problems'; *Jour. Agric. Science*, vol. viii., p. 53.

[7] Cambridge University Department of Agriculture Guide to Experiments, 1907, p. 104.

[8] T. H. Middleton, 'The Formation of Permanent Pastures,' *Jour. Board of Agric.*, vol. xii., pp. 385 and 449.

circumstances (in this case Oxford clay) perennial ryegrass does maintain and even improve its position. It is, however, a common experience of those who have laid land away to grass with ordinary commercial seed that perennial ryegrass does not persist,[9] but neither, for the matter of that, does white clover. And the probability is that the cause in both cases is to be found in the same direction. Both these plants, as usually grown in this and other countries for seed, are the progeny of a long line of cultivated ancestors, grown under somewhat forcing conditions which may be said to undermine the 'constitution.' They have adapted themselves to their artificial environment, and such adaptation has taken the form of early maturity and the production of a large yield of 'bold' seed which is easily marketed. Gilchrist has, of late years, directed attention to the merits of wild white clover,[10] which, as regards persistency, is on an altogether different plane from the cultivated or Dutch white. The price that farmers are willing to pay for the seed of wild white clover is the best proof of the sharp distinction which they draw between the two varieties. What we now want is similar work on grasses, and particularly on perennial ryegrass, and it is satisfactory to know that such work has actually been started.

Other lines of investigation associated with the creation of permanent pasture that might repay research are the relative nutritive values of the more important pasture plants when grown under precisely similar conditions, as also under conditions of soil and climate with which they are naturally associated, and when subjected to the actual process of grazing. In 1853 Way published an account of his analysis of grasses, clovers, and other pasture plants,[11] a line of inquiry that was again followed by Voelcker[12] some thirty years later. In the former case the plants were collected as they grew naturally in the field, while in the latter they were specially grown in plots. A comparison of the two sets of figures does not reveal any consistent agreement, a result that seems to support the view that, in respect of nutritive value and mineral contents, grasses are very sensitive to soil conditions and other factors of the situation. The difficulty of determining the feeding value of pasture by means of chemical analysis was experienced in a marked degree by Hall and Russell, who thus express themselves[13]: 'The only general conclusion one can draw is that the method of food analysis as ordinarily practised gives no measure of the feeding value of such material as grass. It fails to reveal anything to correspond to the very marked differences in habit of the fatting and non-fatting grasses, and none of the results can be interpreted so as to show which of the grasses were poor and which valuable food. . . . Although the difference in feeding value was known to be great, the differences revealed by the ordinary methods of chemical analysis were very small. The ordinary methods are clearly inadequate for dealing with pasture grasses.' It would therefore appear that if further attempts are to be made with a view to differentiating between the various pasture plants in respect of nutritive value, resort will have to be had to the digestive track of animals on lines suggested by the Tree Field Experiments at Cockle Park. Areas large enough to provide grazing for a sufficient number of sheep, and, *a fortiori*, of cattle, present a serious difficulty, and the idea suggests itself that perhaps guinea-pigs or rabbits could be utilised as the medium in small-scale experiments. I should also like to see a test made of the effects of sowing the mixed seed derived from the herbage of good grass land fortified with a pound per acre of the seed of wild white clover, in contrast with a mixture of seeds compounded on the most so-called scientific principles. Nearly twenty years ago I took over a heavy farm on the Weald and created as good pastures as, I believe, the land could carry by applying 7 cwt. of basic slag to the foul stubbles without the

[9] Stapledon and Jenkin, *op. cit.*, p. 26.

[10] D. A. Gilchrist, 'Trials of Wild White Clover.' *Jour. Board of Agric.*, vol. xxii.

[11] J. Thomas Way, 'On the relative Nutritive and Fattening Properties of different Natural and Artificial Grasses,' *Jour. Roy. Agric. Soc. Engl.*, vol. xiv., p. 171.

[12] M. J. Sutton, 'Permanent Temporary Pastures,' 1st Ed., 1886.

[13] *Op. cit.*, pp. 369 and 370.

addition of any seed whatever. I have seen a field of excellent pasture so uniform throughout that no one in a company of farmers and scientific agriculturists could tell any difference between one side and the other, and yet one part of the field was seeded with the most perfect mixture which a leading seedsman could devise, while the other part got no seed at all. The whole field, however, had been well dressed with basic slag. I have still a vivid recollection of sowing down 46 acres to grass in the spring of 1901 on the University Farm at Cambridge. The seed [14] was put in with a thin cover crop of peas and oats, and the weather subsequently proving extremely unsuitable for germination and growth. In July the whole area was a mass of weeds, and few, if any, of the grass and clover plants introduced as seed had persisted. A more derelict-looking piece of ground it would be hard to imagine, and the mowing machine was run over it to clear up the rubbish. But from such an unpromising beginning an excellent pasture has resulted, in my opinion phosphatic manuring, not the primary seeding, being the determining factor.

These are the kind of results that cause one 'furiously to think' whether it is not worth while to investigate along the lines indicated, even if these appear to conflict with conventional practice. For this suggestion I hope I may claim the support of Stapledon and Jenkin, who say, in connection with white clover, 'On many types [of soil] phosphatic manure [is] all that is necessary to hasten the appearance of the indigenous plant,' and, further, 'Undoubtedly when putting land down to long duration grass as much or more can be done by making the habitat as suitable as possible to the desirable indigenous species, as by including their commercial counterparts in the mixture.' [15]

Important as is the position of the fine old pastures of England in the agricultural economy of the country, and interesting though it may be to examine questions of seeding, a much more important line of inquiry is opened up by the problem of the improvement of our second- and third-rate pastures. What proportion of the grass land of the country falls into the lower categories it is impossible to say, but the most superficial acquaintance with rural England is sufficient to carry conviction that the aggregate area of such land is enormous. Most of the poor grass land of the country is associated with the heavier classes of soil, and has been abandoned to grass on account of the high costs of cultivation, including, in many cases, the necessity of drainage. It is, for arable purposes, essentially wheat land, with an occasional crop of beans, and the regular intervention at comparatively short intervals of a bare fallow. Other areas of poor pasture, smaller in aggregate extent than the clays, but still of much importance, are to be found on all the geological formations of the country. Of the 14½ million acres of permanent grass in England and Wales, 70 per cent. is under pasture and only 30 per cent. under hay, and of the poorer classes of grass land it is certain that the proportion that is grazed is still greater. It is evident therefore that the improvement of pasture is relatively a more urgent matter than the improvement of meadows, though with over 4¼ million acres of permanent grass made into hay in England and Wales during 1918, the latter problem is also one of enormous importance. The most famous experiments on the effects of manure on permanent hay are those started in 1856 by Lawes and Gilbert on the Meadow at Rothamsted, and continued ever since on the lines originally laid down. The results have thrown a flood of light on the principles of manuring, which has been of the greatest assistance in the elucidation of problems in agricultural chemistry and soil physics. They have also shown unmistakably the effects of the more important elements of plant food on the yield of hay and on its botanical composition, but even supported as they were by elaborate chemical analysis of the produce, they leave us uncertain in regard to the feeding value of the herbage.

A very large number of experiments have been carried out which had for their object the determination of the quantitative results attributable to the use of manures, singly and in combination. In many cases these experiments were supported by a botanical and not infrequently by a chemical analysis of

[14] Cambridge University, 'Guide to Experiments at Burgoyne's (University) Farm,' 1906, p. 72.

[15] *Op. cit.*, pp. 61-62.

the resultant herbage, but it was felt that we were still in a state of much uncertainty in respect of the quality of the hay, that is to say, its effect on animals consuming it. This induced Middleton [16] in the winter of 1900-1 to carry out a feeding experiment with sheep at Cockle Park, and in 1905-6 and 1907-8 Gilchrist [17] continued and amplified this work. The sheep were accommodated in a special house. The various lots of sheep all got equal quantities of roots, cake, and hay. The hay employed was the produce of variously manured plots on old grass land which I laid out in 1897. The soil is a clay loam on a boulder clay subsoil. This set of experiments includes the eight-plot test, and it may be interesting to see what influence nitrogen, phosphoric acid, and potash respectively have on the produce. The quantitative figures refer to the average annual yield for 21 years, 1897-1917, while the figures which indicate the relative values of the produce, as determined by the live weight increase of sheep, are based upon the feeding tests already specified. The hay from the unmanured plot, No. 6, is assumed to be worth 4*l*. per ton. The results are set out in the accompanying table.

Plot	Manuring per acre per annum	Average Annual Yield of Hay	Value per Ton of Hay as determined by feeding
		cwt.	
6	Unmanured	19¼	80/–
7	30 lb. N in Sulphate of Ammonia .	23	72/–
8	50 lb. P_2O_5 usually in Basic Slag .	26	93/–
9	50 lb. K_2O in Muriate of Potash .	16	80/–
10	30 lb. N+50 lb. P_2O_5 . . .	30¼	84/–
11	30 lb. N+50 lb. K_2O . . .	21	72/–
12	50 lb. P_2O_5+50 lb. K_2O . .	26	101/9
13	30 lb. N+50 lb. P_2O_5+50 lb. K_2O .	30½	89/2

Nitrogen derived from sulphate of ammonia, and used at the rate of 30 lb. per acre per annum, has consistently increased the yield and as consistently reduced the quality. When used alone the nitrogen has increased the crop by 3¾ cwt. per acre, and reduced the feeding value of the hay by 8*s*. per ton. When added to phosphates the nitrogen has increased the yield by 4¼ cwt. and reduced the quality by 9*s*. per ton. When nitrogen was added to potash the yield has been raised by 5 cwt. per acre, and the value lowered by 8*s*. per ton When used as an addition to both phosphates and potash the nitrogen has increased the yield by 4½ cwt. per acre, while the value has fallen by 12*s*. 7*d*. per ton. Even if the quality of the hay be disregarded, the use of nitrogen has always been attended by an adverse financial balance; when quality is taken into account this undesirable result is greatly emphasised.

As regards phosphoric acid, an increased yield has been consistently obtained by its use, accompanied in every case by a marked improvement in the quality of the hay. Taking the arithmetical mean, the increase in quantity has been nearly 8½ cwt. per acre, while the increase in quality is represented by 16*s*. per ton.

The behaviour of potash is rather peculiar. It has quite distinctly reduced the yield when used alone or when used in combination with nitrogen only, while under both these sets of circumstances it has had no influence one way or other on the quality of the hay. When added to phosphates it has proved powerless to increase the yield, but it has raised the feeding value of the hay by 8*s*. 9*d*. per ton. When added to both nitrogen and phosphates the potash has been practically inoperative so far as yield is concerned, but it has improved the quality by 5*s*. 2*d*. per ton.

These results show that very erroneous conclusions may be reached if, in experimental work on meadow hay, attention is only given to the weights of

[16] *Sixth Annual Report on Experiments . . . at Cockle Park*, 1902, p. 19.
[17] *Bulletin No. 8 of Northumberland Education Committee*, 1906, p. 69; and *Guide to Experiments at Cockle Park for* 1916, p. 30.

produce secured. Thus, in these Cockle Park experiments, on the average of 21 years, if quantity alone be regarded, sulphate of ammonia used by itself has involved an annual loss of 6*s*. 4*d*. per acre, whereas, if the reduced quality of the hay be taken into account, the loss is increased to 15*s*. 7*d*. per acre. On the other hand, a quantitative gain of 4*s*. 2*d*. per acre per annum from the use of phosphate and potash is raised to one of 32*s*. 5*d*. owing to the superior quality of the hay. While there is a certain relationship between the chemical composition, the botanical analysis and the feeding value of the hay there will probably be general agreement with Middleton when he says that 'Without an appeal to the animal the relative values of samples grown under different treatment cannot be measured.' In my view this form of research may, with advantage, be largely extended.

It is unnecessary to attempt to abstract the numerous permanent hay experiments which have been a prominent feature of field-plot trials, especially during the past thirty years. These show unmistakably that farmers of meadow land have an attractive opportunity for the judicious expenditure of capital on artificial manures. It is an opportunity which most progressive farmers have embraced, though the condition of wide areas of meadow land shows how much still remains to be accomplished. Broadly speaking, phosphates are the foundation on which manurial improvement is most surely laid, supplemented in most cases by nitrogen, and in many cases by potash. There are numerous instances throughout the country of phosphates alone producing the maximum return in profit and quality, and sometimes even in weight. Thus on a field in East Suffolk, 'of very poor, heavy land that had been untenanted for some years at Rendham and apparently grew nothing but wild carrots and a little rough grass,'[18] quarter-acre plots were laid down in the autumn of 1900. 'The hay crop of 1901 was so poor that it was not considered worth weighing.' But in the subsequent five years the results were very remarkable, the average yield on the unmanured area being 8 cwt. of hay, as contrasted with 35 cwt. on the plot which received a single dressing of 10 cwt. of basic slag. Taking hay at 2*l*. per ton, and therefore making no allowance for the superior quality of the produce, or for residues, the slag gave a return, after deducting its cost, of 12*l*. per acre.[19] But the apparent lack of the need of phosphates for support from added nitrogen is usually associated with the earlier years of such experiments, and such need disappears later. Hall accounts for the superior early action of the phosphate as follows: 'It is not uncommon to find cases where the application to grass land of a phosphatic manure, like super-phosphate or basic slag, is followed by a great increase of crop, the addition of the phosphoric acid to the dormant nitrogen and potash in the soil having supplied the missing element in a complete plant food. . . . A nitrogenous manure alone is often thought exhausting, but probably a phosphatic manure used singly will even more quickly impoverish the soil.'[20] I agree that this argument applies to tillage land growing non-leguminous crops, but it seems to be put too strongly in the case of permanent grass land. In my view the more marked effects of phosphates in the earlier years is due to the fact that when one applies phosphates one is indirectly applying nitrogen as well. But after the first great flush of clovers, and of Leguminosæ generally, this class of plant becomes less abundant, and consequently the fixation of atmospheric nitrogen by the herbage is reduced, and the crop requires and responds to nitrogenous manures. Where, however, there are abundant natural supplies of potash in the soil the stage of marked reduction in fertility of a hay field may be long delayed. Thus on Palace Leas, at Cockle Park, the plot which for over twenty years has annually received nothing but phosphates is showing a larger increase in the hay crop on the average of the last five years than it did on the average of the first five. And not only so, but the addition of

[18] *Report, East Suffolk County Council*, 'Field Experiments, How very poor heavy land Pasture may be improved.'

[19] Cambridge University Department of Agriculture, 'Guide to Experiments,' 1907, p. 150.

[20] A. D. Hall, 'The Manuring of Grass Land,' *Jour. Roy. Agric. Soc. Engl.*, 1903, p. 76.

sulphate of ammonia had distinctly more influence in the first five than in the last five years, and this not only when used alone, but also when it was added to phosphates only, to potash only, or to phosphates plus potash. It would appear, therefore, that here at least—and there must be many other instances—the persistent use of phosphates has not only *not* tended to exhaust the soil of nitrogen, but has positively increased it. By way of measuring the extent of the stored-up fertility in grass land that has been treated with phosphates, I carried out a series of pot experiments on the following lines : Five lots of soil and turf from treated and untreated land from the same fields were placed in pots in which five crops of cereals and mustard were subsequently grown, when it was found that on the average the yield was increased by 27 per cent. This result was quite in conformity with the increase of nitrogen in the soil as disclosed by chemical analysis.[21]

Turning now to the improvement of pastures, as contrasted with meadows, it may be remarked that while no sharp line can be drawn between these two classes of grass land in respect of ameliorative treatment, there are certain distinctions which must be kept in view. In a meadow the plants are allowed to grow up to full maturity, whereas in a pasture they are cut over daily, or at least very frequently, by the grazing of the animals. It is difficult to arrive at a decision as to whether a larger gross weight of dry material is got from a given area treated as pasture, in contrast to being hayed, but the probability is that the aggregate quantity is greater. Take the analogy of a patch of lucerne. Cut three or four times in the season it may yield six tons of dry matter per acre, cut once it would certainly yield much less. Or take the case of cocksfoot; this springs so quickly in the aftermath that the foliage may shoot up six inches almost in as many days, whereas there would be no such growth were the hay not cut over. It is a matter of observation, too, how quickly red clover springs up after cutting, and trees and shrubs which may be growing only a few inches annually when unrestrained may send up stool shoots several feet in length if cut over. It is difficult, however, to bring the question to the test of figures. I have tried to do so by cutting over an area at short intervals by means of a lawn mower, but the presence of extraneous matter, especially worm-castings, vitiated the results.

If there is any doubt as to the greater weight of dry matter produced under a system of grazing, there can be none in respect of its digestibility. This would appear to be the reason why sheep and cattle will fatten on a pasture, whereas the animals would only remain in store condition on the herbage if made into hay.

At one time experiments on the improvement of pasture took the form of temporarily enclosing an area, to which different methods of treatment were applied and of determining the results in terms of hay. Supplementary to such quantitative determination, chemical analysis and botanical separations were often made, but it is evident from the work of the investigators already quoted that the results so obtained may be a very unreliable index of the feeding value of the herbage. In any case the competition between the various classes of plants may be very different in a hay field and in a well-grazed pasture. Again, in a hay field the produce is reaped and cleared off with all the plant food which it contains. In a pasture, on the other hand, there is the daily conversion of vegetable substance into manure and its immediate return to the land. Reflections of that sort induced me in 1896 to arrange a series of experiments where a direct appeal was made to the animal. We all know that in a lot of animals there are certain individuals which possess idiosyncrasies which result in their thriving better or worse than the others. By careful selection, however, and especially by keeping them under observation for a probationary period, this objection may be largely eliminated. The greater the number of animals the more completely is any disturbance due to individual peculiarities got rid of, and for this reason sheep are usually employed in preference to cattle. No one who looks into the details of these 'manuring for meat' experiments can doubt that, not only in broad outline, but even in the finer details, the results are per-

[21] 'Accumulated fertility in Grass Land in consequence of phosphatic manuring,' *Jour. Board of Agric.*, September 1914 and March 1916.

fectly reliable. Involving as they do considerable outlay on fencing, water, weighing machines, etc., and necessitating the use of large areas of uniform land, such experiments were not likely to be undertaken with great frequency, but I have been able to find reports of nine in England,[22] twelve in Scotland,[23] two in Ireland,[24] and one in New Zealand.[25] Two of them are situated at Cockle Park, of which the original in Tree Field has now completed its twenty-third season, while the other in Hanging Leaves has a record of sixteen years.

I propose now to make a brief general survey of the more salient results of this work.

The outstanding feature of these experiments is the great and profitable effect of phosphates. In this material the farmer is placed in possession of an agent of production whose effects on the output of meat, milk, and work from the pastures of this country are only limited by the supplies. In many cases the increase of meat is trebled and even quadrupled, with a return on the original outlay that runs into hundreds per cent. As between the various sources of phosphate there is unmistakable evidence that basic slag is the most effective, not only in respect of aggregate yield of meat, but also, and more particularly, when the net financial return is considered. This conclusion is also reached by Carruthers and Voelcker in a long series of pasture experiments carried out in 1896-9 for the Royal Agricultural Society of England.[26] In these experiments, however, the effects were only estimated by occular inspection. The primary effect of phosphates is due to the marked stimulus that they give to the growth of clovers and other Leguminosæ, and as these plants revel in a non-acid soil the alkaline character of basic slag appears exactly to suit their requirements. It seems highly desirable that a 'manuring for meat' experiment should be conducted with raw phosphates, whose effects on pasture seem distinctly hopeful. Gilchrist dressed a pasture in Northumberland with equal quantities of phosphoric acid derived respectively from basic slag, Belgian and Algerian phosphate, and two and a half years later he reported from occular observation 'that when such mineral phosphates are as finely ground as basic slag the phosphates they contain may be equally effective.' It must be said, however, that this opinion is hardly borne out by the quantitative results obtained on an adjoining meadow where the weight of hay produced by basic slag was distinctly greater than that grown on the plots dressed with the other two phosphates.[27]

In regard to the quantity of phosphatic manure that can most effectively be employed per acre, it would appear that in the case of inferior pasture a heavy initial dressing, say 200 lb. of phosphoric acid or more per acre, is likely to be nearly twice as effective as half this dressing, and therefore actually much more profitable. To secure the best results the Leguminosæ must be rapidly brought up to their maximum vigour, so that they may fully occupy the ground before the grasses have had time to react to the effects of the accumulated nitrogen.

One of the most striking results of these pasture experiments is the long period over which the action of phosphates persists. Even at the end of nine years the meat-producing power of half a ton per acre of basic slag is far from being exhausted. It is not suggested that this persistent action of slag—and no doubt this applies also to any other effective phosphate—is due to unappropriated residues. It is much more probably due to two other causes; (*a*) to the fact that on a pasture in contrast to a meadow manurial elements are kept in

[22] 'Guide to Experiments at Cockle Park for 1918' (Bulletin No. 27). *Jour. Bath and West Soc.* 1910. Cambridge Guide to Experiments, 1907. *Supplement No. 5 to Jour. Board of Agric.*, 1911. Wakerley, 'Manuring for Milk'; Midland Agricultural and Dairy Institute, 1912.

[23] *Trans. High. and Agric. Soc.* 1905 and 1908. Wright, 6th and 10th Reports on Experiments, West of Scot. Agric. Coll. 1905 and 1911. Greig, *Bulletin No. 16 of Aberdeen and North of Scot. Coll. of Agric.*

[24] *Journal of the Department of Agric. for Ireland*, September 1919.

[25] *New Zealand Journal of Agriculture*, 1919, p. 15.

[26] Carruthers and Voelcker, 2nd Report on the Grass Experiments conducted by the Society, *Jour. Roy. Agric. Soc.* 1900, p. 116.

[27] Gilchrist, *Jour. Newcastle Farmers' Club*, 1917.

circulation from the soil to the plant, and from the plant to the animal, and so, to a large extent, back to the soil again; and (*b*) to the accumulation of nitrogen in the form of humus. Poor unprofitable grass is chiefly associated with clay, and it is fortunate that it is precisely on such land that clover responds so markedly to phosphatic manuring. But conspicuous results have also been obtained on deep peat,[28] on light stony loam,[29] on thin chalk,[30] and on chalk covered by clay with flints.[31] Middleton has very fully discussed the conditions under which phosphatic dressings may be expected to give results [32] and ascribes an important place to soil moisture, on which white clover is directly very dependent. The only conspicuous case of failure of phosphates to improve pasture was encountered in Norfolk, where a 'manuring for mutton' experiment was started in 1901. The soil at that station was a hot dry sandy gravel containing 60 per cent. of sand, and there both basic slag and superphosphate were unable to produce any improvement. Wood and Berry attribute this result partly to the presence of abundant natural supplies of citric soluble phosphoric acid, but chiefly to lack of moisture.[33] In reporting on the R.A.S.E. experiments Carruthers and Voelcker in 1900 had already called attention to the dependence of basic slag on soil moisture.[34].

We may now look at the effect of supplementing phosphates with certain other substances. And, first of all, as regards potash. At most of the manuring-for-mutton stations both in England and Scotland there was a plot devoted to the elucidation of the effect of this substance, and although in the great majority of cases the phosphates-plus-potash plot has shown more live-weight increase than phosphates alone, it is only in very rare instances that the gain has been a profitable one. Even on thin soil overlying chalk potash has had little action on pastures. There are several rather conspicuous instances of quite moderate dressings of potash doing positive harm. Thus, at Cockle Park, whereas potash gave an appreciable increase in live weight in the first nine years, it proved positively and progressively injurious during the next two six-year periods. Even on a 'light stony loam' in Perthshire Wright found that although in the first two years potash when added to slag gave a conspicuous return, in the next three years 'the advantage was wholly with the slag alone plot.' The most notable beneficial effect of potash was obtained in Dumfries-shire on a station where the mineral soil was overlaid by ten feet of peat.[35] There the use of kainit supplying 100 lb. of potash per acre at the beginning of the experiment has in seven years produced 70 per cent. more meat than phosphate (slag) alone, while the financial gain has been improved by nearly 50 per cent.

Potash has had great influence both on the yield and composition of the hay on the meadow at Rothamsted, and it would seem that this substance has more effect on a meadow than on a pasture. The reason is probably to seek in the fact that in a pasture the top layers of the soil are constantly being enriched by the potash brought from the subsoil by plants and returned through their excreta. In any case, pasture plants on clay soil are in possession of abundant supplies of potash, and it is only where pasture occupies sandy, gravelly or peaty soil that this manurial element need be seriously considered.

Lime as an addition to superphosphate was tested at the three original manuring-for-cotton experiment stations, a total of 30 cwt. per acre being applied.

[28] Wright, Report on Experiments on the Improvement of poor permanent pasture by manuring, *Bulletin No.* 54, *West of Scot. Coll. Agric.* 1910, p. 173.

[29] *Ibid.*, p. 187.

[30] Somerville, 'Poverty Bottom,' an Experiment in increased Food Production, Miscellaneous Publications of the Board of Agriculture, 1918.

[31] Somerville, 'Influence on the Production of Mutton of Manures applied to Pasture,' *Suppl. Jour. Board of Agric.* 1911, p. 11.

[32] Cambridge University Dept. of Agric., *5th Annual Report on Experiments*, p. 13; and the 'Improvement of Poor Pastures,' *Jour. Agric. Science*, vol. i., p. 122.

[33] Wood and Berry, 'Soil Analysis as a Guide to the Manurial Treatment of Poor Pastures,' *Jour. Agric. Science*, vol. i., p. 114.

[34] *Op. cit.*, pp. 131-2.

[35] *Bulletin No.* 54 *of the West of Scotland Coll. of Agric.*, 1910.

in three dressings in nine years. A noticeable effect was produced at all stations, and at two of them the gain was a profitable one. The effects of lime can be followed for twenty-one years at Cockle Park, where the soil naturally contains 0·59 per cent. of calcium carbonate. During that period an aggregate of five and a half tons per acre was applied in seven dressings, the phosphate to which it was added being superphosphate in the first nine years and basic slag in the next twelve. The area receiving the lime was the same throughout. The action of the lime has proved to be a progressively decreasing one. On the average it produced an annual increase of 22 lb. live weight in the first nine years, and of 8 lb. in the next six years, whereas in the concluding six years of the period it has actually caused a reduction in live weight of 8 lb. per acre per annum. From these figures it would seem that lime has had more effect when used with superphosphate than when basic slag was employed. But already at the end of the ninth year, up to which time superphosphate was alone employed, the effects of lime were noticed to be declining at all the stations, a fact to which I called attention in reporting in 1911 on the influence on the production of mutton of manures applied to pasture,[36] where it is stated 'that in the penultimate and last years [of the first nine] the beneficial action of lime seems to be on the wane,' and where the opinion is expressed 'that the lime is acting rather as a liberator of inert nitrogen than as a direct plant food.' It would appear that this conclusion is confirmed by the experiences of later years. It would seem therefore that Wood and Berry's suggestion in the case of poor pastures is justified—namely, that 'the limit for calcium carbonate below which liming may be expected to be profitable is probably below 0·25 per cent.' [37]

The action of lime on grass land is a large subject, too large, in fact, to be exhaustively pursued here. But I may call attention to a series of experiments which I started on meadow land in Cumberland in 1895, and which have been reported on on several occasions.[38] At certain stations the use of 500 lb. per acre of caustic lime five times in eight years as an addition to a 'complete' manure has markedly decreased the hay crop, and it would appear that this dressing has exceeded the necessities of these soils in respect of 'lime requirement' in the sense of the term as employed by Hutchinson and Maclellan,[39] and that the stage of 'partial sterilisation' has been reached. Against the validity of this suggestion, however, there is the fact that the depressing influence of the lime was manifest in the first year. While there is evidence that lime as an agent in the improvement of pasture is a substance to be used with caution, it would appear that where there is a large accumulation of sour humus it is only through the use of lime that this can be got rid of, and the way thereby prepared for further improvement by the use of phosphates.

The addition to superphosphate of moderate dressings of nitrogen in the form of sulphate of ammonia or of nitrate of soda was tried at the three main manuring-for-mutton stations, and at two others. There is no need to go into a detailed discussion of the results. The evidence is overwhelmingly against the use of nitrogen on pastures. It undoubtedly stimulates the vigour of the non-leguminous herbage, but this reacts on the growth of the clovers, with the result that the production of meat is sometimes, as at Cockle Park, actually and substantially reduced.

At the three original stations dissolved bones were also tried, the comparison being with equal quantities (200 lb. per acre in nine years) of phosphoric acid derived respectively from basic slag and superphosphate. The dissolved bones supplied in addition from about 30 to 40 lb. of organic nitrogen. All manures were applied as to half of the first year, and, as to the other half, at the commencement of the fourth season, the experiment being continued for nine years

[36] *Supplement No.* 5 *of the Jour. Board of Agric.*, p. 50.

[37] *Op. cit.*, p. 117.

[38] Somerville, *Eighth Annual Report on Experiments, in the Counties of Cumberland, Durham and Northumberland*, p. 28. T. H. Middleton, *Tenth Annual Report*, p. 87. D. A. Gilchrist, *Eleventh Report*, p. 26.

[39] H. B. Hutchinson and K. Maclellan, *Jour. Agric. Science*, vol. vi., p. 302, and *ibid.*, vol. vii., p 73.

at Cockle Park and Sevington (Hants) and for eight years at Cransley (Northants). At Cockle Park slag acted substantially better than dissolved bones, though the latter surpassed the effect of superphosphate; at Sevington dissolved bones proved inferior to both the other manures; while at Cransley the position was reversed. But when the cost is considered there is no question of the superior merits of basic slag. This superiority is continued and emphasised at Cockle Park where the experiments are now at the end of their twenty-third year. A similar result was also obtained in the series of pasture experiments conducted by the Royal Agricultural Society of England already referred to. There dissolved bones or bone meal was tried at ten centres, with the result that 'in Herefordshire some benefit was observed, but in the other places no real improvement could be detected as compared with the unmanured part of the field. So far as these investigations go, therefore, they indicate that no further experiments need be made with bones on pasture land.'[40]

With these results before us it is needless to pause to consider whether the comparative failure of bones, dissolved or raw, is due to the inferior quality of their phosphate, or to the fact that they supply the land with nitrogen.

A form of pasture improvement which has had, and still has, much support amongst farmers is feeding with cake. The manure applied to the land through cake residues is a 'general' manure, supplying nitrogen, phosphates, and potash, of which that which has the highest value attached to it is the nitrogen. At eleven of the stations in England and Scotland reported on in the Supplement to the 'Journal of the Board of Agriculture' in 1911,[41] linseed or cotton cake, or a mixture of these cakes, was used for two, four, or five years, and at every one of them the live-weight gain secured was insufficient to pay for the outlay, the debit balance per acre per annum being in one case nearly a pound. In connection with the improvement of pasture, however, it is the residual effect of the cake that has most interest. This matter was put to the test at eight of the manuring-for-mutton stations in the following manner. At the three original stations cake was fed all through the season for two years, and none given for the next four. At the other five stations cake was fed for two or four years, and was then suspended for one, two, or three years. In this way the improvement of the herbage effected during the years when cake was fed had an opportunity of manifesting itself in the form of live-weight increase in the years immediately succeeding, when no cake was given. In every case the residual effect was found to be appreciable, having a money value per ton of cake consumed of as much as 4*l*. 14*s*. at one station, and 3*l*. 11*s*. at another, the average for the three stations where the residues were followed for four years being fully 3*l*. per ton, a figure which is of the same order as, though somewhat higher than, those adopted by Voelcker and Hall in their revised table of 1902.[42]

At Cockle Park on Tree Field the question of the immediate and residual effects of decorticated cotton cake has been pursued through twenty-one years. After the first stage of nine years, cake was fed for three years, and its residues tested for the succeeding three years, and similarly in the next period of six years. In this connection I cannot do better than quote from Gilchrist's Reports. Commenting on the second six-years period, he says, 'Decorticated cotton cake fed to the sheep on plot 1 in the first three years gave a small gain in these years, but throughout the six years the average annual gain amounts to only 9*d*. an acre.'[43] As to the third period of six years he reports, 'Decorticated cotton cake fed to the sheep on plot 1 in the first three years has resulted in an annual loss of 11*s*. 9*d*. an acre. . . . It is notable that the cake has not given a profitable return from the sheep in the years when it was fed to them, and it has had little unexhausted value in the later years. Nitrogen from the cake has had the same effect on the herbage of this plot as nitrogen from the nitrate of soda on plot 9, and the herbage is still of a coarse and benty character.'[44] This, on land which has had about $2\frac{1}{2}$ tons per acre

[40] *Op. cit.*, p. 135.
[41] *Op. cit.*, p. 22.
[42] *Jour. Roy. Agric. Soc. Engl.*, vol. 36, p. 111.
[43] 'Guide to Experiments for 1917,' p. 13.
[44] 'Guide to Experiments for 1918,' p. 15.

of a rich cake fed at intervals during twenty-one years is a poor showing, and justifies the conclusion that as an ameliorative agent cake occupies a low position as compared with an effective phosphate like basic slag.

A method of improvement of poor pasture that deserves notice consists in scattering the seed of a 'renovating' mixture over the surface, usually with concurrent harrowing, rolling, and manuring. This procedure was practised in the series of experiments conducted by the Royal Agricultural Society of England, the seed mixture consisting of four natural grasses in addition to white clover and yarrow.[45] In their final report Carruthers and Voelcker stated that re-seeding had not been successful, a result which they thought was 'entirely due to the prevalence of dry seasons, the germinating plants being killed before they could get hold of the soil.' A more successful result is reported by Middleton,[46] who on a poor pasture on clay soil in Essex, sowed, in the spring of 1903, 12 lb. per acre of wild white clover seed, with and without basic slag, kainit, and lime, this treatment being unaccompanied by harrowing. There were no Leguminosæ naturally present in the field. Helped by abundant rain in the summer of 1903, when in the London area in June 'rain fell without cessation from midday on the 13th to midnight on the 15th; and at Camden Town the total in fifty-eight hours amounted to nearly 3½ inches,'[47] the seed germinated well, and 'in 1904 the results were very marked.' It was, however, only when the seeding had been accompanied by basic slag that 'there was the luxuriant growth which one expects in pastures where Leguminosæ are present.'

Middleton came to the conclusion that 3 lb. per acre of white clover seed would have been enough, and that ordinary white clover seed, as contrasted with seed from the wild plant, would serve the purpose. Middleton carried out this experiment in the early days of 'wild white,' and probably he would now agree with the suggestion that this variety possesses properties which mark it off rather sharply from the cultivated variety, and that the two, for permanent purposes, are not interchangeable. I also have reported on an experiment where renovating a thin poor pasture with 6 lb. per acre of wild white clover seed was entirely successful, and here, too, the beneficial effects were only secured in the presence of basic slag.[48]

It would appear, therefore, that where the herbage of a pasture is thin, so as to permit of a considerable proportion of the seed reaching the soil, and especially in the absence of natural Leguminosæ, renovation through the agency of wild white clover seed, with concurrent phosphatic manuring, is likely to be successful. Drought, however, at a critical stage of the growth of the young plants may prove fatal, but such a contingency will be best avoided by seeding in early autumn rather than in spring.

The many experiments, and ordinary farming experience, show clearly how poor pastures may be profitably improved in the first instance, but an important matter still remains to be discussed—namely, the means to be adopted to maintain the improvement.

When a responsive pasture is treated, for the first time, with say half a ton of basic slag per acre, the effects reach their maximum usually in the third season. From then onwards there is a steady diminution in the yield, though even after nine years from the time of the initial dressing the improvement is far from being exhausted. At Cockle Park, for instance, the plot dressed once with half a ton of slag was, at the end of nine years, producing three times as much mutton as the continuously unmanured ground, while at Sevington and Cransley the yield, at the end of nine and eight years respectively, was 70 to 80 per cent. greater. None of the other stations was carried on for so long a period, but up to the end of the sixth year most of them show residual fertility which is as great as the original rental value of the land.[49] That is a very important result, but in the interests of the country it is still

[45] *Jour. R.A.S.E.*, 1898, p. 148.
[46] *Jour. Agric. Science*, vol. i., p. 136.
[47] *Ibid.*, 1913, p. 415.
[48] 'Poverty Bottom,' p. 6.
[49] *Supplement No. 5 to Jour. Board of Agric.*, 1911, p. 28.

more important to endeavour to secure that the level reached at the period of maximum productivity shall be maintained.

Some information on this point is furnished by the three manuring-for-mutton stations at Cockle Park, Sevington, and Cransley. At each of these places a plot was dressed with 100 lb. of phosphoric acid derived from slag, and for the fourth season thereafter the dressing was repeated, nothing more being applied for the succeeding six years. At each of the stations there was an immediate response; at Cockle Park the repeated dose acted considerably better than the first; at Cransley the effects of the two dressings were practically identical, only at Sevington was the effect of the first dressing considerably better than that of the second.[50] This subject can be followed for twenty-one years at Cockle Park, where, since the end of the ninth year, 10 cwt. of slag per acre (200 lb. P_2O_5) are applied every six years to Plot 3, as contrasted with 5 cwt. (100 lb. P_2O_5) every three years to Plot 4, another plot receiving at the same time 100 lb. P_2O_5 in the form of 7 cwt. of superphosphate. The information we want is as to whether these dressings of phosphates have been able to maintain the high state of productiveness which we know was secured by the initial doses of these substances. The figures bearing on this point are brought together in the accompanying table.

Average annual Live-Weight increase per acre for the same 3-year periods.

	No Manure	5 cwt. Slag every 3 years[51]		7 cwt. Super. every 3 years[51]	
	Actual Increase	Actual Increase	Gain due to Slag	Actual Increase	Gain due to Super.
	lb. L.W.	lb. L.W.	lb. L.W.	lb. L.W.	lb. L.W.
1st dose of manure .	46	90	44	88	42
2nd ,, .	36	131	95	126	90
3rd ,, .	23	115	92	106	83
4th ,, .	24	86	62	98	74
5th ,, .	20	98	78	103	83
6th ,, .	23	108	85	101	78

Average annual Live-Weight increase per acre for the same 6-year periods.

	No Manure	10 cwt. Slag every 6 years[52]	
	Actual Increase	Actual Increase	Gain due to Slag
	lb. L.W.	lb. L.W.	lb. L.W.
1st dose of manure . .	41	137	96
2nd ,, . .	23	117	94
3rd ,, . .	22	112	90

It will be seen, in the first place, that the production of the unmanured plot has manifestly declined from the earlier years, a result partly due to the lighter stocking and partly to the shorter grazing season. Confining attention for the moment to the upper section of the table, it may at once be said that the high level of productivity induced by the second dressings both of slag (5 cwt.) and superphosphate (7 cwt.) has not been maintained, the cause being probably due, in large part, to a six-year interval occurring between the second and third doses. But there is a distinct tendency for the live-weight increase to rise in the later stages, and, on the whole, it may be said to be conclusively demonstrated

[50] *Supplement No. 5 to Journ. Board of Agric.*, 1911, p. 36.

[51] The 5 cwt. slag and 7 cwt. super. were applied every 3rd year, except that there was an interval of 6 years between the 2nd and 3rd doses.

[52] The slag was applied every 6th year, except that there was an interval of 9 years between the 1st and 2nd doses.

that on this particular class of land fertility has been well maintained by moderate dressings of slag or superphosphate at three-year intervals.

As regards the larger dressing of slag (lower section of table) it will be seen that here also absolute productivity is not maintained at the high level of the earlier years, though as between the ninth and fifteenth years the reduction is very slight. But comparing the production on the manured and unmanured land it will be seen that in these three tests the proportionate increase of meat as a result of repeated doses of phosphates is actually greater at the end of 21 years than it was in the beginning, the ratio rising from 2·3 :1 to 4·1 :1. In other words, for every pound of meat produced on the unmanured land 5 lb. are being produced on the manured ground, and not only so, but the enhanced production is being secured at a cost which leaves a very large profit on the improvement.

The power of repeated moderate dressings of slag to maintain the improvement produced by a large initial dressing of this substance is well illustrated in another series of experiments commenced at Cockle Park in 1903. A field (Hanging Leaves) of poor pasture on clay was equally treated in 1898 with about 6 cwt. of slag per acre. No further treatment was given till 1903 when 4 plots, each 10·1 acres in extent, were fenced off, and to all of them 10 cwt. per acre of slag was given. Since that time a supplementary dressing of 5 cwt. per acre of slag has been given to Plot 1 every 3 years, with the result that at the end of 15 years of this treatment the production of live-weight increase (in this case both cattle and sheep) is nearly as high (200 lb. per acre, average 3 years 1915-17) as at the stage of maximum production (206 lb. per acre, 1906-8). Here, as on Tree Field, under the influence of slag the meat produced is nearly five times as great as on the untreated ground.[53]

Another plot, No. 2, is concerned with the question as to whether cake can be profitably fed to cattle and sheep on land which has first been graded up with a liberal dressing of basic slag. Both Plots 1 and 2 have had the same amount of basic slag since 1898 (36 cwt. per acre) applied at the same time, the only difference in the treatment being that the stock on Plot 2 have since 1904 consumed 3 cwt. of rough cotton cake per acre, except in 1917 when a mixture of palm-kernel and earth-nut cakes was substituted. The quantity consumed up to the end of 1917 is thus practically 2 tons per acre. The cake has in the aggregate in 14 years added about 470 lb. to the live-weight increase per acre produced by slag alone. This increase at present-day rates is valued at less than 9*l*., to secure which the expenditure on cake is estimated at about 26*l*., so that the direct and indirect effects of the cake have been extremely unprofitable. As a matter of fact, whereas slag alone gives an annual profit of more than 2*l*. per acre, the use of cake on slagged land reduces the profit to less than 1*l*. Clearly, therefore, cake-feeding on this class of land, which is receiving basic slag, is not a commercial success.

Another aspect of the same problem is dealt with on Plot 3. Both this plot and No. 1 received the same initial dressing of slag—namely, ½ ton per acre for 1903—the differential treatment since that year consisting in No. 1 receiving every 3 years 5 cwt. of slag, whereas No. 3 has had 3 cwt. per acre per annum of rough cotton cake fed upon it. The comparison, in fact, is between the feeding value (indirect) of 5 cwt. of slag and the feeding value (direct and indirect) of 9 cwt. of cotton cake. The results, with those on the other plots, are shown in the table on page 16.

For the first two years, when no supplementary slag had been applied, the cake appeared to give a good account of itself, but the first supplementary dressing of slag distinctly reduced the difference in the two sets of live-weight figures, after which the output of Plot 1 (slag) steadily improved, while that of Plot 3 (cake) as steadily, and more markedly, declined, until in the period 1915-17 the slag was producing 55 lb. per acre per annum more animal increase than the cake. It would appear therefore that the accumulated cake residues have had a positively injurious effect on the pasture, and that this effect is being accentuated as time goes on.

The fourth plot is concerned with the question as to the value of organic nitrogen in fish meal as compared with the nitrogen in cake residues. Plots 2

[53] Gilchrist, 'Cockle Park Guide,' 1919, p. 17.

Cockle Park, Hanging Leaves Experiment (All Plots received per acre about 6 cwt. Slag for 1898 and 10 cwt. for 1903).

——	Plot 1. 5 cwt. Slag every 3 years	Plot 2. Same as Plot 1, but also 3 cwt. Cotton Cake fed annually	Plot 3. Same as No. 2, but no Supplementary Slag	Plot 4. Slag (4 cwt.) and Fish Meal ($3\frac{1}{2}$ cwt.), supplying P_2O_5 and N equal to that contained in the Cake and Supplementary Slag of No. 2
——	Average L.W. gain per acre per annum	Average L.W. gain per acre per annum	Average L.W. gain per acre per annum	Average L.W. gain per acre per annum
1904–5	151	207	204	153
1906–8	206	251	227	225
1909–11	187	213	161	187
1912–14	189	210	150	190
1915–17	200	227	145	179
1918	218	242	142	167

and 4 got the same initial dressing of slag (10 cwt. per acre) for 1903, since which year the stock grazing on Plot 2 have eaten 3 cwt. per acre per annum of cotton cake. In addition, this plot has every 3 years (commencing with 1906) received 5 cwt. per acre of slag. Plot 4 has every 3 years received 4 cwt. per acre of slag and $3\frac{1}{2}$ cwt. of fish meal, the slag and fish meal combined being estimated to supply P_2O_5 and nitrogen equal to these substances contained in the 5 cwt. of slag and 9 cwt. of cotton cake given every 3 years to Plot 2. The cake plot (No. 2) has yielded in the aggregate of 14 years about 470 lb. more live-weight increase, but as the cost of doing so has been about 14*l.* the balance of profit is much in favour of Plot 4. As in the case of Plot 3 (cake alone after initial dressing of slag) the productivity of Plot 4 is distinctly on the down grade, and both as regards the live-weight increase and net returns it compares very unfavourably with Plot 1, which received the same initial treatment as regards slag, and subsequently was dressed at 3-year intervals with 5 cwt. of slag, instead of 4 cwt. of slag and $3\frac{1}{2}$ cwt. of fish meal. It seems to be quite clearly proved, therefore, that on such pasture land as Cockle Park the addition of nitrogen to phosphates is most detrimental, and no doubt for the reason that it encourages grass to the disadvantage of clover.

From this rapid survey of grass-land experiments the following conclusions may legitimately be drawn :—

1. That the quality of a pasture is not primarily dependent on its botanical composition, though, as a rule, the presence of white clover and other Leguminosæ is indicative of high feeding value.
2. That poor pastures, especially on clay soil, can be rapidly and profitably improved by the use of phosphates, especially basic slag.
3. That, as a rule, phosphates alone are sufficient to effect and maintain the improvement, and that, of supplementary substances, potash and lime are occasionally worthy of attention.
4. That the improvement of poor pasture is very dependent on the presence of Leguminosæ, and especially of white clover.
5. That renovating with the seed of wild white clover may, in the absence of natural Leguminosæ, be a necessary preliminary or concurrent operation.
6. That cake can rarely be used at a profit, and that, as an agent in improving poor pasture, it occupies an unsatisfactory position.
7. That nitrogen, whether in the form of artificial manure, or as cake residues, when added to phosphates for pasture, is always unnecessary and frequently detrimental.
8. That, in the case of hay on permanent grass land, equal weights of produce may have very different feeding values.
9. That few forms of agricultural expenditure are more certain in their results

than the judicious use of manures on grass land, and that the meat and milk producing capacity of the country can be largely and rapidly increased, with great pecuniary gain to the farmer, and still greater economic advantage to the nation.

The following Papers were then read :—

1. *The Past Neglect and Future Improvement of Live-Stock in British Husbandry.* *By* K. J. J. Mackenzie, *M.A.*

No serious well-wisher to the future of home farming should fail to note that, while the pedigree breeders of Great Britain supply the rest of the world with live-stock of transcendent quality, the husbandman of the home country has often to be satisfied with animals that are as bad as any the civilised world can produce.

The cause of this is not far to seek. Pedigree live-stock, wanted for food or cloth-production by the overseas exporter, had to be specimens of their kind supremely useful as begetters of animals capable of thriving upon uncultivated soil. Animals demanding assistance from the cultivators of land were not required by those whose object was to secure all possible gain from vast areas of land without more effort than is required in turning out animals to fend for themselves. The circumstances overseas were better adapted for this class of land robbery than those found in our own country, and it came about that better prices could be obtained for breeding stock suitable for the overseas market than for those fulfilling the requirements of such cultivation as was going on at home. Consequently these latter were neglected by the breeder seeking adequate remuneration for his enterprise.

If it be determined that there is to be a change in the national programme, and that our husbandmen are to be encouraged to work for greater production and not be left to obtain such profit as any unintensive system of farming may yield, consideration of their requirements as regards live-stock must be given precedence over those of the customer coming from overseas—*Education*, *Research*, and *Co-operation* must be harnessed to serve the interests of the farmer, who requires suitable animals to further his efforts whilst working in close proximity to our great industrial areas, so that he may win from the land of the United Kingdom food which will be at hand in any hour of need.

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2. *The Value of Lupins in the Cultivation of Poor Light Land.* *By* A. W. Oldershaw, *M.B.E.*, *B.Sc.*[1]

Lupins grow with remarkable luxuriance on very light land, poor in lime. At the present time, owing to economic conditions, there is grave danger that considerable areas of this type of land will go out of cultivation. It would appear that an extended growth of lupins offers one of the simplest methods of rendering economically possible the cultivation of this land, and possibly of reclaiming what is already derelict.

Owing to their deep-rooting habit, and their powers of assimilating the free nitrogen of the air, lupins greatly enrich the soil, and whether ploughed in green, folded with sheep, or harvested for seed, leave a considerable quantity of residue upon the ground, which is of great value to the succeeding crop. Very heavy crops of rye are being grown this year after lupins, on land actually adjoining the heath.

When folding, care must be taken not to allow the sheep to eat too much or they will suffer from paralysis owing to lupin poisoning. Suffolk flockmasters fold their sheep on lupins with confidence, and do not regard the risk as serious. Sheep take some time to get accustomed to the bitter flavour of lupins, but thrive remarkably well once they have become used to them. They cannot live satisfactorily on lupins alone, but must have access to other food.

[1] Sec. *Journ. Board of Agriculture*, Dec., 1919; also *Modern Farming*, Dec., 1919.

There is often some difficulty in disposing of lupin seed, owing to the fact that it contains some poisonous substance, and is very bitter. In Suffolk lupin grain is fed to sheep at a rate not exceeding half-a-bushel per day per 100 sheep, and the feeding must commence gradually. If too much is fed the sheep become paralysed. It is claimed in Holland that a method has been discovered whereby the poisonous principle can be extracted, and the grain rendered fit for stock-feeding purposes. If this could be done it would give a great stimulus to lupin-growing, and would be a considerable advantage to light-land farmers, as lupins might then occupy the same place on light land as is occupied by beans on heavy land.

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3. *The Composition of Linseed recovered from a Flax Crop.* *By* T. W. Fagan, *M.A.*[2]

The demand for flax fibre during the war has resulted in a great revival of the ancient practice of flax cultivation in Scotland, and in 1918 over a thousand acres were sown in the county of Fife. Although grown for fibre the seed was also saved and the opportunity taken of obtaining samples of the seed for analysis, particularly for the determination of their oil content.

The seed supplied was of Dutch origin and a sample taken from bulk contained 39·20 per cent. of oil; the seed was sown at the rate of 126 to 140 lb. per acre in loamy soils that varied from light to heavy and ranged in altitude from 100 to 560 feet above sea-level. The yield of seed in Fife was on the average 7 cwt. per acre.

The samples received for analysis were of two kinds : (1) Linseed cleaned with the usual appliances of a farm; (2) properly cleaned and dressed linseed.

	Percentage of Oil	
	(1)	(2)
Average of 20 samples . .	32·5	36·15

The difference was due to the high percentage of weed seeds in the uncleaned sample.

Flax having the reputation of being an exhausting crop, determinations were made of the nitrogen, phosphoric acid, and potash in the seed, the capsules de-seeded, and the stem and roots.

As careful records of the whole crop were kept, the amounts of each of these ingredients removed per acre by the crop were found to be as follows :—

	Lb. per acre		
	Nitrogen	Phosphoric Acid	Potash
Flax seeds, 7 cwt.	28	11	9·87
Flax capsules, 7 cwt. . . .	8	3·5	11·00
Flax stem and roots, 27 cwt. . .	7	7·7	17·23
	43	22·2	38·10

It will be seen that the amount of nitrogen, phosphoric acid, and potash removed is very similar to that taken up by an ordinary cereal crop.

WEDNESDAY, SEPTEMBER 10.

The following papers were read :—

1. *War-time Food Production in England and Wales.* *By* Sir T. H. Middleton, *K.B.E., C.B.*

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[2] See *Scottish Journ. of Agriculture*, Vol. ii., No. 4, Oct., 1919.

2. *On Increased Food Production in Scotland.*

By J. M. Caie, *M.A., B.Sc., B.L.*

An essential difference in the agricultural conditions under which the schemes for increased food production were undertaken in Scotland, as compared with those prevailing in England, is exemplified by the following figures relating to the year 1917 :

Country	Percentage of Total Cultivated Area under	
	Permanent Grass	Rotation Grass
Scotland	30%	31%
England	58%	9%

The increased cropping was therefore to be secured much less by ploughing up old grass land and more by a shortening of the rotations on arable farms than was the case in England.

A certain increase was obtained in 1917, but the most active campaign was in respect of the 1918 crop.

The Board of Agriculture for Scotland acted through sixty-five District Agricultural Executive Committees, who were asked to arrange for a total increase of 350,000 acres, the area for 1918 being 317,450 acres. This represented approximately 7½ per cent. of the area under permanent grass and 17½ per cent. of that under rotation grass.

In 1918 an actual increase of 241,000 acres was obtained in the area under grain (wheat, barley, and oats), beans, and potatoes, amounting approximately to 75 per cent. of the extension aimed at. The increase consisted chiefly of 18,300 acres of wheat, 198,600 acres of oats, and 21,600 acres of potatoes. The area under barley was diminished by 5,800 acres, and that under turnips and swedes by 17,800. The decrease in permanent grass was 107,000 acres, or 7½ per cent., and in rotation grass 136,000 acres, or 9 per cent.

It is a notable fact that the increased cropping was obtained without any appreciable reduction in the numbers of horses, cattle, and sheep, while the decrease of 4 per cent. in the number of pigs was probably due mainly to other causes, such as the increased cost of feeding stuffs.

The method of administration of the food-production scheme differed, to some extent, in Scotland from that in England, as the general principle adopted was that the increased cultivation should be undertaken as far as possible on a voluntary basis, compulsory orders under the Defence of the Realm Regulations being resorted to only where occupiers were unable or unwilling to do what the Board, acting in consultation with the Committees, thought might be reasonably required of them. The Board accordingly did not delegate their powers under these Regulations to the Committees, whose function, very successfully fulfilled, was to obtain definite promises from occupiers, and, failing these, to report cases to the Board for further negotiation and, if necessary, the issue of orders. In the vast majority of cases so reported, these further negotiations achieved the desired results. In the two years 1917 and 1918 less than 200 orders were issued for the whole of Scotland; under fifty-seven of these land was entered on and taken possession of, under 113 the occupiers were required to cultivate in accordance with stated requirements, while in only nine cases was it necessary to terminate tenancies. Prosecutions for failure to cultivate as required—all followed by conviction—numbered eleven.

It is believed that a noteworthy feature of the schemes for increased food production in Scotland will be their relatively low cost to the State. No special Food Production Department of the Board was set up; the number of officials attached to the Committees was kept down to a minimum (usually one, or at most two, to each Committee, many of them being officers of the Agricultural Colleges); the small number of compulsory orders will correspondingly limit the total claims for compensation thereunder; and already a large proportion of the Board's tractors and implements have been disposed of at satisfactory prices.

Some general considerations will be submitted as to the effects on Scottish agriculture of the movement for increased food production, and particularly of the greater intervention of the State in the control of the industry.

3. *War-time and Post-war Problems of Crop Production.* *By* E. J. Russell, *O.B.E., D.Sc., F.R.S.*

4. *The Outlook in Dairying.* *By* J. Mackintosh.

5. *The Electrical Treatment of Seeds.* *By* Dr. A. M. Blackburn.

THURSDAY, SEPTEMBER 11.

The following Papers were read :—

1. *The Classification of Cattle Foods.* *By* J. Alan Murray, *B.Sc.*[1]

Object of classification.—To bring together in natural groups those foods that are of similar character and quality, irrespective of the concentration of the nutrients in them.

The customary arrangement.

1. Fresh products—roots, grasses, clovers, leaves, &c.
2. Dry foods { Coarse—straws, hays, &c. / Fine—grains, meals, cakes, &c.

Though convenient for certain purposes, this is not a scientific classification, and does not accomplish the object in view.

The criterion of quality is the amount of available energy or starch equivalent per lb. of dry matter, and this should be made the basis of classification. If the foods are arranged in this order the distinction between fresh and dry vanishes, and no sharp line of demarcation between coarse and fine can be drawn, but the foods can be arranged in groups according to quality, and then may be sub-divided according to the amount of digestible protein.

The more important foods in the main natural groups are as follows :

1. Cereal and pulse straws.
2. Inferior hays.
3. Grasses and clovers in flower, good hays, undec. cotton cake.
4. Mangels, pasture grass, wheat bran, brewers' grains.
5. Swedes, molasses, cabbages, oats, pollards, rape cake.
6. Potatoes, barley, sharps, peas, beans, decort. cotton cake.
7. Locust beans, rye, wheat, middlings, cotton seed, maize germ cake, palm-nut cake, linseed cake.
8. Maize, maize meal, gluten meal, gluten feed.

The thesis accounts in a satisfactory manner for the proved productive efficiency of roots, for the differences in productive value of pastures, and, probably, also for the improvement in grass due to application of phosphatic manures.

Practical conclusions.—Hay should be cut early; pastures should be closely grazed; nitrogenous manures should be used sparingly, and phosphatic manures

[1] The subject of this paper is also referred to in an article on 'The Nutritive Value of Feeding Stuffs' in *Science Progress*, No. 54, Oct., 1919.

freely, on grass lands; silage is not an efficient substitute for roots; roots may be substituted to a large extent for purchased meals and cakes, and considerable pecuniary economy may be thereby effected.

Joint Meeting with Section K.—See Section K., p. 337.

FRIDAY, SEPTEMBER 12.

Sectional Excursion to Iwerne Minster.

On Gauss's Theorem for Quadrature and the approximate Evaluation of definite Integrals with finite Limits. *By* Prof. A. R. Forsyth, F.R.S.

(Ordered by the General Committee to be printed *in extenso*.)

1. Most of the rules commonly used for the mechanical quadrature of smooth non-re-entrant curves require the measurement of ordinates at equal distances apart; the greater the number of ordinates, the closer the approximation. The same remark applies to the approximat evaluation of definite integrals. If, in particular, n ordinates are used the process can fairly be described as taking the ordinate of the curve or the subject of integration, at the value x as equal to

$$a_0 + a_1 x + \ldots + a_{n-1} x^{n-1},$$

and implicitly determining the n constants a by means of the magnitudes at the n places.

There is, however, a remarkable theorem due to Gauss whereby the accuracy of the approximation can be nearly doubled. The ordinates are to be measured at places, not equally distant apart, but at selected positions in the range. These selected positions do not depend upon the special curve or upon the form of the subject of integration. For an assigned number of ordinates, the division of any range is exactly similar to that of any other range and depends only upon this assigned number. So far as is known to me, the rule or rules derived from the theorem [1] are not applied in ordinary practice; and my purpose in this note is to recall attention to the utility of these rules, by giving them in a form that requires nothing more than numerical substitution.

The theorem can be enunciated as follows:—

The approximate value of the integral $\int_q^p f(x)dx$ can be made as accurate as though $2n-1$ equidistant ordinates are measured, if only n ordinates are measured at the places given by the roots of the equation

$$\frac{d^n}{dx^n}\left\{(x-p)^n (x-q)^n\right\} = 0.$$

The mathematical statement of the theorem can be simplified by substituting

$$x = \tfrac{1}{2}(p+q) + \tfrac{1}{2}(p-q)\,y,$$

and taking

$$f(x) = \phi(y).$$

[1] In its original form, the theorem was stated and proved by Gauss in his memoir *Methodus nova . . . . inveniendi* (1814), Ges. Werke, iii., pp. 163–196. A different proof was given by Jacobi, Ges. Werke, vi., pp. 3–11; and it is reproduced in Moulton's edition of Boole's *Finite Differences* (p. 52). Part I. of the second volume of Heine's *Kugelfunctionen* may be consulted.

But, as already remarked, the theorem is not applied in ordinary practice, although its theory has received considerable additions.

The integral becomes

$$\tfrac{1}{2}(p-q)\int_{-1}^{1}\phi(y)\,dy.$$

The equation giving the positions of the selected ordinates is

$$\frac{d^n}{dy^n}\left\{(y^2-1)^n\right\}=0;$$

that is, the positions are given by the roots of

$$\mathrm{P}_n(y)=0,$$

where P_n is the Legendre function (the Zonal Harmonic) of order n. All the n roots are known to be real, and they lie between $+1$ and -1. If n is even, the roots are equal and opposite in pairs. If n is odd, one root is zero and the remaining roots are equal and opposite in pairs.

2. Let $\alpha_1, \ldots, \alpha_n$ be the roots of $\mathrm{P}_n(y)=0$; then

$$\mathrm{P}_n(y)=\mathrm{N}\prod_{r=1}(y-\alpha_r),$$

where the constant N is immaterial to our purpose. The Lagrange formula of interpolation now is

$$\phi(y)=\Sigma\frac{\phi(\alpha_r)}{\mathrm{P}_n'(\alpha_r)}\frac{\mathrm{P}_n(y)}{y-\alpha_r};$$

and so

$$\int_{-1}^{1}\phi(y)\,dy=\Sigma\mathrm{A}_r\phi(\alpha_r),$$

where

$$\mathrm{A}_r=\int_{-1}^{1}\frac{\mathrm{P}_n(y)}{y-\alpha_r}\frac{dy}{\mathrm{P}_r'(\alpha_r)}.$$

Two cases arise, according as n is odd or is even.

(i) Let n be odd and equal to $2p+1$, where p is an integer. The roots of $\mathrm{P}_n(y)=0$ are $y=0$, and $y=\pm\alpha_r$ (for $r=1, \ldots, p$); so

$$\mathrm{P}_n(y)=\mathrm{N}y(y^2-\alpha_1^2)(y^2-\alpha_2^2)\ldots(y^2-\alpha_p^2).$$

Thus

$$\mathrm{P}_n'(0)=\mathrm{N}(-1)^p\alpha_1^2\alpha_2^2\ldots\alpha_p^2,$$

$$\mathrm{P}_n'(\alpha_s)=2\mathrm{N}\alpha_s^2\overset{s}{\Pi}(\alpha_s^2-\alpha_t^2),$$

where Π denotes the product of $\alpha_s^2-\alpha_1^2$, $\alpha_s^2-\alpha_2^2$, $\ldots$, $\alpha_s^2-\alpha_p^2$, with the omission of the factor $\alpha_s^2-\alpha_s^2$; and

$$\mathrm{P}_n'(-\alpha_s)=2\mathrm{N}\alpha_s^2\overset{s}{\Pi}(\alpha_s^2-\alpha_t^2).$$

The value of A_0, corresponding to the root $y=0$ of $\mathrm{P}_n(y)=0$, is

$$(-1)^p\int_{-1}^{1}\frac{(y^2-\alpha_1^2)\ldots(y^2-\alpha_p^2)}{\alpha_1^2\ldots\alpha_p^2}\,dy,$$

so that

$$\mathrm{A}_0=2\frac{(-1)^p}{\alpha_1^2\ldots\alpha_p^2}\left\{\frac{1}{2p+1}-\frac{\Sigma\alpha_1^2}{2p-1}+\frac{\Sigma\alpha_1^2\alpha_2^2}{2p-3}-\ldots\right\}.$$

The value of A_s corresponding to the root $y=a_s$ of $P_n(y)=0$ is

$$\int_{-1}^{1} \frac{y(y+a_s)\overset{s}{\Pi}(y^2-a_t^2)}{2a_s^2\overset{s}{\Pi}(a_s^2-a_t^2)}\,dy.$$

But the integral

$$\int_{-1}^{1} y\overset{s}{\Pi}(y^2-a_t^2)\,dy$$

is zero, because the subject of integration is an uneven function of y consequently

$$A_s=\int_{-1}^{1}\frac{y^2\overset{s}{\Pi}(y^2-a_t^2)}{2a_s^2\overset{s}{\Pi}(a_s^2-a_t^2)}\,dy$$

$$=\frac{1}{a_s^2\overset{s}{\Pi}(a_s^2-a_t^2)}\left\{\frac{1}{2p+1}-\frac{\overset{s}{\Sigma}a_1^2}{2p-1}+\frac{\overset{s}{\Sigma}a_1^2a_2^2}{2p-3}-\ldots\right\},$$

where, in the sums, Σ denotes that a_s^2 must not occur.

The value of A corresponding to the root $y=-a$ of $P(y)=0$ is

$$\int_{-1}^{1}\frac{y(y-a_s)\overset{s}{\Pi}(y^2-a_t^2)}{2a_s\overset{s}{\Pi}(a_s^2-a_t^2)}\,dy.$$

Because of the vanishing integral

$$\int_{-1}^{1} y\overset{s}{\Pi}(y^2-a_t^2)\,dy,$$

the value of this coefficient A is

$$\frac{1}{a_s\overset{s}{\Pi}(a_s^2-a_t^2)}\left\{\frac{1}{2p+1}-\frac{\overset{s}{\Sigma}a_1^2}{2p-1}+\frac{\overset{s}{\Sigma}a_1^2a_2^2}{2p-3}-\ldots\right\},$$

that is, it is equal to A_s.

Thus we have

$$\int_{-1}^{1}\phi(y)\,dy=A_0\phi(0)+\overset{p}{\underset{s=1}{\Sigma}}A_s\left\{\phi(a_s)+\phi(-a_s)\right\},$$

with the stated values of $A_0, A_1, \ldots, A_p$, in the case when n is equal to the uneven integer $2p+1$.

It should be noted that

$$A_0+2\overset{p}{\underset{s=1}{\Sigma}}A_s=2;$$

an immediate inference from the simplest form of $\phi(y)$ taken as a constant.

Reverting to the earlier integral with the x-range from p to q, we write

$$\begin{aligned} c_0 &= \tfrac{1}{2}(p+q),\\ c_s &= \tfrac{1}{2}(p+q)+\tfrac{1}{2}(p-q)a_s,\\ c_s' &= \tfrac{1}{2}(p+q)-\tfrac{1}{2}(p-q)a_s; \end{aligned}$$

then

$$\phi(\alpha_s)=f(c_s),\ \phi(-\alpha_s)=f(c_s'),$$

and we finally have

$$\int_q^p f(x)dx=\tfrac{1}{2}(p-q)\left[\mathrm{A}_0 f(c_0)+\Sigma\,\mathrm{A}_s\{f(c_s)+f(c_s')\}\right].$$

(ii) Let n be even and equal to $2q$, where q is an integer. The roots of $\mathrm{P}_n(y)$ are $y=\pm b_r$ (for $r=1, \ldots, q$); so $\mathrm{P}_n(y)$ is equal to $\mathrm{M}(y^2-b_1{}^2)(y^2-b_2{}^2)\ldots(y^2-b_q{}^2)$.
Thus

$$\mathrm{P}_n'(b_s) \quad =2\mathrm{M}\,b_s\,\Pi\,(b_s{}^2-b_t{}^2),$$

and

$$\mathrm{P}_n'(-b_s)=-2\mathrm{M}b_s\overset{s}{\Pi}(b_s{}^2-b_t{}^2).$$

The value of constant A, corresponding to the root $y=b_s$ of $\mathrm{P}_n(y)=0$, is

$$\int_{-1}^{1}\frac{(y+b_s)\overset{s}{\Pi}(y^2-b_t{}^2)}{2b_s\overset{s}{\Pi}(b_s{}^2-b_t{}^2)}dy,$$

which, for the same kind of reason as before, is equal to

$$\tfrac{1}{2}\int_{-1}^{1}\frac{\overset{s}{\Pi}(y^2-b_t{}^2)}{\overset{s}{\Pi}(b_s{}^2-b_t{}^2)}dy,$$

that is,

$$\mathrm{A}_s=\frac{1}{\overset{s}{\Pi}(b_s{}^2-b_t{}^2)}\left\{\frac{1}{2q-1}-\frac{\overset{s}{\Sigma}b^2}{2q-3}+\frac{\overset{s}{\Sigma}b^2b_2{}^2}{2q-5}-\ \ldots\right\}.$$

The value of the constant A, corresponding to the root $y=-b_s$ of $\mathrm{P}_n(y)=0$, is (on evaluation) the same as that of the constant A_s. Thus, as before, but with these values of the constant A_s, we have

$$\int_q^p f(x)dx=\tfrac{1}{2}(p-q)\left[\Sigma\mathrm{A}_s\left\{f(c)+f(c_s')\right\}\right],$$

with the same literal significance for c_s and c_s', viz.,

$$c_s=\tfrac{1}{2}(p+q)+\tfrac{1}{2}(p-q)b_s,$$
$$c_s'=\tfrac{1}{2}(p+q)-\tfrac{1}{2}(p-q)b_s.$$

It should be noted that, in this expression,

$$\Sigma\mathrm{A}_s=1.$$

3. Some of the simplest cases will now be taken.

I. Let $n=3$, so that $p=1$. The equation $\mathrm{P}_3(y)=0$ gives

$$5y_3-3y=0$$

so that $\alpha_1{}^2=\frac{3}{5}$. Then

$$\mathrm{A}_0=-\frac{2}{\alpha_1{}^2}(\tfrac{1}{3}-\alpha_1{}^2)=\tfrac{8}{9},$$

$$\mathrm{A}_1=\frac{1}{\alpha_1{}^2}\cdot\tfrac{1}{3}=\tfrac{5}{9};$$

and therefore

$$\frac{1}{p-q}\int_q^p f(x)dx=\tfrac{1}{18}\left\{5f(c_1')+8f(c_0)+5f(c_1)\right\},$$

where

$$c_1' =\tfrac{1}{2}(p+q)-\tfrac{1}{2}(p-q)\,(\tfrac{3}{5})^{\frac{1}{2}}=\tfrac{1}{2}(p+q)-\cdot3873(p-q),$$
$$c_0 =\tfrac{1}{2}(p+q),$$
$$c_1 =\tfrac{1}{2}(p+q)+\tfrac{1}{2}(p-q)\,(\tfrac{3}{5})^{\frac{1}{2}}=\tfrac{1}{2}(p+q)+\cdot3873\,(p-q).$$

As an example, let it be required to find the value of

$$\frac{2}{\sqrt{\pi}}\int_0^1 e^{-x^2}dx$$

approximately. We have

$$c_1'=\cdot1127\ ,\ c_1'^2=\cdot0127\ ,\ e^{-c_1'^2}=\cdot9874,$$
$$c_0 =\cdot5\ \ \ \ ,\ c_0^2=\cdot25\ \ \ ,\ e^{-c_0^2}=\cdot7788,$$
$$c_1 =\cdot8873\ ,\ c_1^2=\cdot7873\ ,\ e^{-c_1^2}=\cdot4551\ ;$$

then

$$\tfrac{1}{18}(5e^{-c_1'^2}+8e^{-c_0^2}+5e^{-c_1^2})=\cdot7468.$$

Multiplying by $\frac{2}{\sqrt{\pi}}$, we find as the approximate value ·84268.

The value of $\frac{2}{\sqrt{\pi}}\int_0^1 e^{-x^2}dx$ as given in the tables is ·84270; the approximation in this example is closer than in other examples and must be affected by the special form of the subject of integration.

II. Let $n=5$, so that $p=2$. The quantities α_1^2 and α_2^2 are the roots of

$$63t^2-70t+15=0,$$

and we take

$$63\alpha_1^2=35+(280)^{\frac{1}{2}},\ 63\alpha_2^2=35-(280)^{\frac{1}{2}}$$

Further,

$$A_0=\frac{2}{\alpha_1^2\alpha_2^2}\left\{\tfrac{1}{5}-\tfrac{1}{3}(\alpha_1^2+\alpha_2^2)+\alpha_1^2\alpha_2^2\right\}$$
$$=\frac{128}{225},$$
$$A_1=\frac{1}{\alpha_1^2(\alpha_1^2-\alpha_2^2)}(\tfrac{1}{5}-\tfrac{1}{3}\alpha_2^2)$$
$$=\frac{161}{450}-\frac{91}{45(280)^{\frac{1}{2}}}=\cdot2369,$$
$$A_2=\frac{161}{450}+\frac{91}{45(280)^{\frac{1}{2}}}=\cdot4786\ ;$$

and so

$$\frac{1}{p-q}\int_q^p f(x)dx=\frac{64}{225}f(c_0)$$
$$+\tfrac{1}{2}A_1\left\{f(c_1)+f(c_1')\right\}$$
$$+\tfrac{1}{2}A_2\left\{f(c_2)+f(c_2')\right\},$$

where

$$c_0=\tfrac{1}{2}(p+q),$$
$$c_1,\ c_1'=\tfrac{1}{2}(p+q)\pm\tfrac{1}{2}(p-q)a_1,$$
$$c_2,\ c_2'=\tfrac{1}{2}(p+q)\pm\tfrac{1}{2}(p-q)a_2.$$

As an example, let this rule be required to find an approximate value of

$$\int_1^{10}\frac{dx}{x},$$

that is, of $\log_e 10$. Here

$$f(c_0)=\frac{1}{\frac{11}{2}},$$

$$f(c_1)=\frac{1}{\frac{11}{2}+\frac{9}{2}a_1},\quad f(c_1')=\frac{1}{\frac{11}{2}-\frac{9}{2}a_1},$$

$$f(c_2)=\frac{1}{\frac{11}{2}+\frac{9}{2}a_2},\quad f(c_2')=\frac{1}{\frac{11}{2}-\frac{9}{2}a_2};$$

when these are substituted in the formula, and reduction is effected, we find approximately

$$\frac{1}{9}\int_1^{10}\frac{dx}{x}=\cdot0517+\cdot0957+\cdot1078$$
$$=\cdot2552,$$

and therefore the approximation, given by this rule, for $\log_e 10$ is 2·2968. The accurate value to the same number of places of decimals is 2·3026; so that the error is about ·25 per cent.

III. Let $n=7$, so that $p=3$. The quantities a_1^2, a_2^2, a_3^2 are the roots of

$$429t^3-693t^2+315t-35=0,$$

arising out of $P_7(y)=0$ on the rejection of the root $y=0$ and the substitution $y^2=t$. When this cubic equation is solved by Horner's method, its roots are

$$a_1^2=\cdot90081\ldots,\quad a_2^2=\cdot54987\ldots,\quad a_3^2=\cdot16471\ldots,$$

and so

$$a_1=\cdot9491\ldots,\quad a_2=\cdot7415\ldots,\quad a_3=\cdot4058\ldots$$

Now

$$A_0 = \frac{2}{a_1^2 a_2^2 a_3^2}\left\{ \tfrac{1}{7} - \tfrac{1}{5}(a_1^2+a_2^2+a_3^2) + \tfrac{1}{3}(a_1^2a_2^2+a_2^2a_3^2+a_3^2a_1^2) - a_1^2a_2^2a_3^2 \right\},$$

$$A_1 = \frac{\tfrac{1}{7} - \tfrac{1}{5}(a_2^2+a_3^2) + \tfrac{1}{3}a_2^2a_3^2}{a_1^2(a_1^2-a_2^2)(a_1^2-a_3^2)},$$

$$A_2 = \frac{\tfrac{1}{7} - \tfrac{1}{5}(a_3^2+a_1^2) + \tfrac{1}{3}a_3^2a_1^2}{a_2^2(a_2^2-a_1^2)(a_2^2-a_3^2)},$$

$$A_3 = \frac{\tfrac{1}{7} - \tfrac{1}{5}(a_1^2+a_2^2) + \tfrac{1}{3}a_1^2a_2^2}{a_3^2(a_3^2-a_1^2)(a_3^2-a_2^2)}.$$

When the foregoing values of a_1^2, a_2^2, a_3^2 are substituted in each of the quantities A_1, A_2, A_3, and the symmetric functions of a_1^2, a_2^2, a_3^2 are substituted in A_0, and when reductions are effected, it is found that an approximate value of the integral

$$\frac{1}{p-q}\int^{p} f(x)dx$$

is given by the expression

$$\cdot 2090 f(c_0) + \cdot 0647\left\{ f(c_1)+f(c_1') \right\} + \cdot 1399\left\{ f(c_2)+f(c_2') \right\} + \cdot 1909\left\{ f(c_3)+f(c_3') \right\},$$

where

$$c_0 = \tfrac{1}{2}(p+q),$$
$$c_1,\ c_1' = \tfrac{1}{2}(p+q) \pm \tfrac{1}{2}(p-q)a_1,$$
$$c_2,\ c_2' = \tfrac{1}{2}(p+q) \pm \tfrac{1}{2}(p-q)a_2,$$
$$c_3,\ c_3' = \tfrac{1}{2}(p+q) \pm \tfrac{1}{2}(p-q)a_3.$$

As an example, the rule was applied to a carbon print of a steam indicator diagram; and other rules were applied to other carbon prints of the same diagram. The measurements were made for me by Mr. F. Lord, a demonstrator in my department in the Imperial College of Science and Technology. And a planimeter measurement of these prints was made for me by Mr. W. E. G. Sillick, a lecturer in the same department. The results were as follows:—

The Engineers' rule of the ten mid-ordinates, whereby the diagram is divided into ten compartments of equal breadth and the mid-ordinates are measured, gave ·452 L square inches as the area, where L is the breadth of the diagram. The planimeter measure of the same print of the diagram gave ·455 L as its area.

The Weddle rule for another print of the diagram gave ·445 L as the area. The planimeter measure for this print gave ·455 L as its area.

The first of the preceding Gauss rules (with only three ordinates) gave ·44 L as the area of a third print. The second of the preceding Gauss rules (with five ordinates) gave practically ·460 L as its area, the last place of decimals being very slightly appreciated. The third of the Gauss rules gave ·460 L as its area, there being no appreciation in the

last place of decimals. The planimeter measure of the print gave ·458 L as its area.

A steam indicator diagram is small; and so, in using a planimeter, considerable skill is required to obtain good results. The first of the Gauss rules gives a fairly good result, seeing that only three ordinates are measured; and it may be regarded as sufficient for some practical purposes. The second of the Gauss rules, with five ordinates, give as accurate a result as can be obtained in the ordinary circumstances of the degree of accuracy of measurements. But for the approximate value of an integral, much greater accuracy is often desirable; and so the Gauss seven-ordinate rule would be more effective, seeing that it gives as accurate a result as would be obtained by taking thirteen equidistant measures of the subject of integration.

It should be pointed out that a steam indicator diagram possesses the smooth quality assumed by the analysis which is used in establishing Gauss's rule. But a Diesel diagram often does not possess this quality; and so the rules cannot always be expected to give similarly satisfactory results for Diesel diagrams. A skilful use of the planimeter is, of course, effective.

4. The preceding examples arise from the cases when the order of the Legendre function is odd. A single example will suffice to indicate the form when the order is even. We shall take $n=4$.

The places where the ordinates are to be measured are given by the roots of the equation $P_4(y)=0$; that is, if $y^2=t$, we have

$$35t^2-30t+3=0,$$

and therefore

$$35a_1^2=15+(120)^{\frac{1}{2}},\ 35a_2^2=15-(120)^{\frac{1}{2}}.$$

Then

$$\begin{aligned} A_1&=\frac{1}{a_1^2a_2^2}\left(\tfrac{1}{3}-a_2^2\right)\\ &=\tfrac{1}{2}-\frac{5}{3(120)^{\frac{1}{2}}}=\cdot 34785,\\ A_2&=\frac{1}{a_2^2-a_1^2}\left(\tfrac{1}{3}-a_1^2\right)\\ &=\tfrac{1}{2}+\frac{5}{3(120)^{\frac{1}{2}}}=\cdot 65215. \end{aligned}$$

We then have, by this rule,

$$\frac{1}{p-q}\int_q^p f(x)dx=\tfrac{1}{2}A_1\left\{f(c_1)+f(c_1')\right\}+\tfrac{1}{2}A_2\left\{f(c_2)+f(c_2')\right\},$$

where

$$\begin{aligned} c_1,\ c_1'&=\tfrac{1}{2}(p+q)\pm\tfrac{1}{2}(p-q)a_1,\\ c_2,\ c_2'&=\tfrac{1}{2}(p+q)\pm\tfrac{1}{2}(p-q)a_2. \end{aligned}$$

Chemical Warfare. *By* Brigadier-General H. Hartley, *C.B.E., M.C.*

(Ordered by the General Committee to be printed *in extenso.*)

One of the most striking contrasts between the late war and those which preceded it is the rapid development of scientific and mechanical methods of warfare, which resulted from the concentration of most of the scientists and engineers of the world on war problems. Of the new developments none was more far reaching in its effects on land than the introduction of gas and smoke, and on the sea smoke played an important part in naval tactics.

The object of this paper is to sketch the development of gas warfare, to show the ways in which gas proved itself a valuable weapon, and to describe the nature of the problems with which British chemists were confronted and their success in solving them.

First Use of Gas by the Germans.

Gas was employed during the war in two ways, in cylinders and in projectiles. In the first method of attack, a gas such as chlorine, which could be liquefied at atmospheric temperatures by a moderate pressure, was compressed in large steel cylinders from which it could be discharged rapidly just as from a soda-water syphon. These cylinders were taken into the trenches and large numbers were discharged on a continuous front when the wind would carry the gas over the enemy's lines. In the second method, part of the explosive charge of a shell was replaced by gas, which could thus be used independently of the wind direction. Both methods were introduced by the Germans almost simultaneously in April 1915.

Two reasons have been given to explain their introduction of gas into warfare. Firstly, when the German supplies of high explosives were found to be insufficient after the battle of the Marne, they began to consider the possibility of increasing their total output of shell by using gas which could be manufactured without interfering with the production of high explosives. Secondly, preliminary bombardments with H.E. and shrapnel had failed to guarantee the success of an infantry attack; the need was felt of some new types of shell to supplement the action of the old. But there was another and more powerful reason for the introduction of the new weapon—the knowledge of the advantage to be gained by a surprise use of lethal gas contrary to the Hague Convention.

The first German cylinder attack was made by means of chlorine on April 22, 1915, against the French on a frontage of about four miles in the north of the Ypres salient. The effect of a cloud of chlorine on unprotected troops is easily imagined: for some distance behind the line all were killed or rendered incapable of offering any resistance. It was a great opportunity for a decisive stroke, but the Germans failed to take advantage of it. The quantity of gas used was too small to make it effective to a great distance, the front of discharge was comparatively short, and the Germans failed to exploit the partial success they gained. Two days later a second cloud attack was made on the British front against the Canadians with similar results. In May four more attacks took place, but in these our troops were protected partially with hastily improvised respirators and suffered much less severely. After May no more cloud attacks were made on the British front until December 19, 1915, when an attack of a more formidable nature was made to the N.E. of the Ypres salient. Cylinders were used containing a mixture of phosgene and chlorine, and a much higher concentration of gas was obtained. However, our troops were equipped with a respirator that gave adequate protection, and only those who were surprised or who failed to adjust their respirators properly, became casualties. Five similar cloud attacks

took place in 1916, each consisting of a short discharge of a very high concentration, so as to obtain the maximum effect of surprise. No serious attempt was made to follow up any of these later discharges with an infantry attack, as our troops were now fully protected and the opportunity for a 'break through' offered by the earlier gas attacks was not likely to occur. The last German cloud attack on the British front was on August 8, 1916.

British Use of Cloud Gas.

Immediately after the first use of gas in April 1915, steps were taken for effective reprisals on our part. The Special Companies R.E. were formed under the command of Major (later Brigadier-General) C. H. Foulkes, C.M.G., D.S.O., R.E., consisting largely of chemists who were specially enlisted as corporals for this purpose. After seven weeks' training in France they carried out our first gas attack with chlorine cylinders at Loos on September 25, 1915. After that date cloud attacks were carried out frequently by us as we had the advantage of the direction of the prevailing wind, and the operations of the Special Companies proved so successful that they were soon expanded into a Special Brigade R.E. in which many of the original chemical corporals received commissions. By the end of the war the Brigade had carried out 768 gas operations in which 5,700 tons of gas were liberated. Twenty-five per cent. of these operations were cloud discharges, the remainder being trench mortar or projector attacks. In addition the units of the Brigade were frequently employed in producing smoke clouds which played an important part in infantry attacks.

Abundant evidence exists both in captured documents and in prisoners' statements of the heavy casualties and loss of morale which the enemy suffered as a result of the operations of the Special Brigade, and their enterprise and gallantry were repeatedly mentioned in despatches by the Commander-in-Chief.

German Use of Gas Projectiles.

The Germans employed shell containing gas on the British front at the same time as their first cloud attack, the contents of the shells being crude brominated xylene or brominated aliphatic ketones. Both substances cause considerable inconvenience owing to their lachrymatory effect on the eyes, but have not a high toxic value. As the wind was usually unfavourable for the German use of cloud gas, their efforts were mainly directed to the development of the gas shell. Employed in this way gas is a much more flexible weapon than in cylinders as its use is far more independent of atmospheric conditions, and a much wider range of substances can be used with properties suited to different tactical purposes. Certain little-known organic compounds were selected as being most suitable, and thanks to the technical resources of the German dye industry, a monthly output was soon obtained amounting to several hundred tons of organic derivatives, which prior to the war had only been prepared in small quantities in the laboratory.

In the summer of 1916, chlormethyl chloroformate, a liquid (B.P. 105° C.) with toxic properties similar to those of phosgene, was used against us in large quantities during the battle of the Somme. Later this was replaced by trichlormethyl chloroformate, a similar liquid (B.P. 128° C.), which was used until the end of the war as the well-known Green Cross shell filling. The use of phosgene in trench mortar bombs also began in 1916.

In April 1917, during the Arras battle, a variant of the Green Cross filling appeared containing 50 per cent. of chlorpicrin (B.P. 112° C.), a lachrymator with asphyxiant properties against which the P.H. Helmet offered no protection, but, as our troops were already equipped with a box respirator, the new filling had no advantage over the old.

In July 1917, just before the third battle of Ypres, Yellow Cross and Blue Cross gas shells (so named after their markings) were introduced, each of which had novel properties. Yellow Cross shell contained dichlorethyl sulphide (B.P. 217° C.), commonly known as 'Mustard Gas' on account of its smell, or as Yperite. The properties of this substance make it a most effective battle gas.

Owing to its slight smell it is less easily detected than other gases, and, although it produces no immediate sensations of discomfort, exposure to a very low concentration is sufficient to put a man out of action owing to the effects of the gas on the eyes and the lungs. As the liquid has a low vapour pressure at atmospheric temperature and reacts very slowly with water, it may remain for days on the surface of the soil and continue to produce a dangerous concentration of gas. In addition to its effects on the eyes and lungs, serious blisters are produced either by splashes of the liquid or contact with any objects contaminated with it. Blue Cross shell contained bottles of diphenylchlorarsine, a solid melting at 46° C., which when finely divided causes sneezing, irritation of the nose and throat, nausea and intense pain. The bottles of this substance were embedded in high explosive, and it was expected that the burst of the shell would scatter the arsenic compound as a fine dust, which would penetrate our respirators and cause such violent sneezing as to make the wearing of the mask impossible. However, the Blue Cross shell failed almost entirely to achieve its object, and in 1918 diphenylcyanoarsine (M.P. 23° C.) was substituted for diphenylchlorarsine without any noticeable changes in the efficiency of the shell. It is probable that favourable results had been obtained with these substances in the laboratory, which could not be reproduced under field conditions. The failure of the Blue Cross shell, many millions of which were fired, is a striking proof of the necessity of having an experimental station at which thorough field trials of any new developments can be carried out before these are put into service use.

Two other substances were used in large quantities by the enemy, phenylcarbylamine chloride, a strong lachrymator (B.P. 209° C.), first used in September 1917, and dichlorethyl arsine (B.P. 156° C.), first used early in 1918, which causes irritation of the nose and throat, headache, and temporary loss of feeling in the extremities.

Thus by the beginning of 1918 the Germans had a number of different gas shells which could be divided into two main classes from the point of view of their tactical employment :—

(*a*) Those containing liquids such as dichlorethyl sulphide which persist for long periods in the soil and can therefore only be used on ground which it is not intended to attack or occupy.

(*b*) Those containing relatively volatile liquids such as trichlormethyl chloroformate or ethyl dichlorarsine, or solids such as diphenylchlorarsine, which can be used immediately before an attack.

In his preparation for the offensive of March 1918, the enemy relied to a considerable extent on the use of gas projectiles, which had never been used before in such large numbers. Eighty per cent. of the ammunition allotted for some purposes contained gas, and it was estimated that several million rounds of gas shell were fired on March 21. From that date until the end of the war a large proportion of gas shell was used by the enemy in all offensive and defensive operations.

British Use of Gas Projectiles.

Gas shell and trench mortar bombs containing lachrymators were first used by the British during the battle of the Somme, but it was not until the battle of Arras in April 1917 that our supplies of gas shell were sufficient to make them effective. Large quantities both of lachrymatory and of lethal shell were used for harassing purposes during the night before the attack at Arras, and their success in interfering with artillery fire and in preventing the movement of troops and transport is described in the following extract from a confidential report, dated 11.4.17, from the General Commanding the First German Army, on 'Experiences in the Battle of Arras' :—

> The enemy made extensive use of gas ammunition against our front positions as well as against batteries. It has not yet been established whether they employed a new gas. Our gas masks afforded complete protection; however, the fighting resistance of the men suffered considerably from wearing the mask for many hours. Horses were greatly affected by the gas—

in many cases the failure of the ammunition supply is to be attributed to this. From the same cause it seems that the timely withdrawals of batteries could not be effected. Artillery activity seems to have been paralysed by the effect of the gas.

During the later months of 1917, especially during the third battle of Ypres, we continued to use gas shell with increasing effectiveness, as was proved by the material results, by numerous captured documents and by prisoners' statements. It happened repeatedly that the enemy's artillery fire ceased abruptly when their batteries were fired on with gas shell, and prisoners admitted that batteries were put out of action in this way. Most of the movement immediately behind the lines necessarily took place during the night, and the gas shelling of tracks interfered seriously with ration parties and reliefs moving over muddy ground composed mainly of deep shell holes full of water. Prisoners often said that ration parties had been compelled to abandon their journey owing to the difficulty of moving in the dark when wearing a gas mask, and the following extract from a prisoner's statement is typical of the difficulty of carrying out a relief :—

> A dense cloud of gas with a strong irritant action lay across the route of the relieving Battalion. The 5th Company attempted to pass through it at a slow double without putting on their masks, since owing to the number of shell holes in the road, the men would have been unable to make their way along if wearing masks. On reaching the gas cloud some of the men tried to put on their masks, with the result that they fell into shell holes; the others were affected by the gas, and finally the whole company went back in disorder to their starting-place.

'Mustard Gas' was first used by us in September 1918 in the successful attack on the Hindenburg line. The French had used it three months earlier, and the results obtained showed that the enemy was taken completely by surprise and suffered heavy casualties. Apparently the Germans had not thought it possible that the technical resources of the Allies would be capable of producing this substance in large quantities in so short a time, and their first idea was that the French had filled shells with liquid taken from their 'blinds.' Examination in the laboratory showed that it had been made by a method entirely different from their own, and at the date of the Armistice they were considering the possibility of adopting the Allies' method of manufacture.

In October, 1916, the 'Livens Projector,' a new type of trench mortar for firing gas bombs, invented by Major W. H. Livens, D.S.O., M.C., R.E., was used for the first time, and in 1917 it developed into one of the deadliest weapons of trench warfare. By means of the 'projector' large numbers of bombs containing 50 per cent. of their weight of gas could be fired simultaneously on to important targets, producing very high concentrations of gas without any warning beyond the flash and noise of the discharge and the bursting of the bombs. The following extracts from a telegram from German General Headquarters dated August 8, 1917, and from two reports on the 'projector' attacks show the effectiveness of the new method of discharging gas :—

> The English have achieved considerable success by firing gas-mines simultaneously from a considerable number of projectors on to one point. The casualties occurred because the gas arrived without warning and because its concentration was so great that a single breath would incapacitate a man.

Extract from Report of Fourth German Army on a Projector Attack at Merris on May 23-24, 1918.

> Shortly after midnight the enemy carried out a heavy surprise bombardment with H.E. ammunition, at the same time a projector attack was made with phosgene drums. The recognition of the nature of the bombardment was made extraordinarily difficult for the troops. The garrison was taking cover, and only a few of them noticed the bright flash of the projector discharge.
>
> Even though the British have so often violated the technical laws of gas

warfare as regards wind conditions, it is still surprising that they should have carried out a gas attack on the night in question. . . .

Casualties : 11 men killed.
121 men gassed (including 2 officers).

To the credit of the troops it must be emphasized that their good discipline and skill in the use of their masks enabled them to avoid even greater losses.

Extract from Divisional Report on Projector Discharge at Ablainezeville, June 18-19, 1918.

Only part of the garrison saw the flash of the discharge, and the flash and the ensuing explosion were mistaken for an enemy ammunition dump going up. Direct hits in or close to dug-outs led to the rapid development of such a concentration of gas that the occupants could not get their masks on in time. The installation of projectors had been suspected, and all regiments had been warned, so that the troops were not taken unawares.

Casualties : 2 officers killed.
57 other ranks killed.
66 other ranks gassed.

The following extract from an order from the Seventeenth German Army shows that the effect of surprise had not been lost even as late as July 1918 :—

Owing to the severe losses we have suffered and to the impossibility of providing our troops with a more convenient form of protection the Army Commander is obliged to resort to more stringent precautions.

(*a*) On all nights when it is neither raining heavily nor blowing hard special sentries are to be posted over all dug-outs.
(*b*) On such nights all ration parties and working parties will make the last 1000 yards of their journey to the front line with respirators adjusted.
(*c*) Respirators will be adjusted at every burst of artillery fire.

Value of Gas as a Weapon.

The above extracts from German documents illustrate some of the ways in which gas proved itself effective, and some of the reasons which make it such a valuable addition to existing weapons.

It has added many complications to war. The possibility of its use compels everyone to carry a respirator, which means additional weight and additional training. When a man wears a respirator his fighting efficiency is diminished owing both to the interference with his vision and to the additional fatigue, and a respirator cannot be worn for an unlimited period, as it must be removed to enable a man to eat and drink. The introduction of gas increased in many ways the strain on troops in the trenches. Elaborate precautions are necessary to ensure a gas alarm being given promptly, many additional sentries being necessary for this purpose, and much extra work has to be done, for example, in rendering all dug-outs gas proof. In addition there is the moral effect of gas, due no doubt largely to ignorance and to an exaggerated notion of its possibilities, but an effect that must always be reckoned with. The Germans tried to exploit this before their attack at Verdun in 1916 and their offensive in 1918 by circulating rumours of the terrible effects of the new gases they intended to use.

Gas shell differ in their effects from other types of shell and can be made to supplement them in many ways. For instance, although deep dug-outs give complete protection against H.E. and shrapnel, gas will enter quickly unless the entrance is protected, and the burst of a gas projectile near the entrance often proved fatal to the occupants. Then again the effects of a bombardment may be prolonged for many hours or even days by the use of a persistent gas, and important areas may be rendered untenable for long periods except to troops

wearing respirators. Owing to the economy of ammunition effected by means of a persistent gas shell, results can be obtained which would be impossible with any of the older types.

The effects of gas shell are not so much limited by a rigid trajectory as those of other projectiles, *e.g.*, H.E. shell are often of little value unless direct hits are obtained, while any gas shell bursting to the windward of a target will affect it, if they fall within a certain distance of it, depending on the calibre of the shell.

Under suitable atmospheric conditions the results obtained with gas shell are often more certain than those with other projectiles. For instance, troops marching along a road shelled with shrapnel might escape with small losses if they were fortunate, while if shelled with gas they would be compelled to wear respirators, thereby hampering their movements, and any lack of precautions would lead inevitably to casualties.

The general impression that gas is an inhumane weapon is derived partly from the German breach of faith in using it contrary to the Hague Convention, and partly from the nature and number of casualties in the earliest cloud attacks which were made against unprotected troops. Under the stress of a long war the individual is apt to forget the physical and mental sufferings it involves, unless he is in daily contact with them, but a dramatic occurrence such as that of the first gas attack forces on the imagination the brutal significance of war—the struggle for victory by killing—and the new weapon is judged as inhumane, like gunpowder in the fifteenth century. If we accept war as a possibility, the most humane weapon is that which leads to a decision with the smallest amount of human suffering and death. Judged from this standpoint, gas compares very favourably with other weapons during the period when both sides were fully equipped for offence and defence. The death-rate among gas casualties was much lower than that among casualties from other causes, and not only was the death-rate lower, but a much smaller proportion of the injured suffered any permanent disability. There is no comparison between the permanent damage caused by gas, and the suffering caused to those who were maimed and blinded by shell and rifle fire. It is now generally admitted that in the later stages of the war many military objects could be attained with less suffering by using gas than by other means.

The judgment of future generations on the use of gas may well be influenced by the pathetic appeal of Sargent's picture of the first 'Mustard Gas' casualties at Ypres, but it must not be forgotten in looking at that picture that 75 per cent. of the blinded men he drew were fit for duty within three months, and that had their limbs and nerves been shattered by the effects of high explosive, their fate would have been infinitely worse.

Work of British Chemists in Connection with Gas Warfare.

Offensive Research.

The foregoing sketch of the development of gas warfare gives some indication of the urgency and importance of the problems with which British chemists were confronted in 1915. Their solution on the offensive side required a research organisation for studying the toxic properties of known substances and for producing new ones that were likely to be more effective, for devising means for their employment and for testing their value under field conditions, and for working out methods of production on a large scale.

Offensive research was carried out originally under the advice of the Scientific Advisory Committee and later of the Chemical Advisory Committee of the Ministry of Munitions, while defensive research was done in the Anti-Gas Department of the War Office. This separation of offensive and defensive research was unfortunate, as many of the problems were common to both sections. In October 1917 the two organisations were united in the Chemical Warfare Department of the Ministry of Munitions under the controllership of Major-General H. F. Thuillier, C.B., C.M.G., who had been the first Director of Gas Services in France. The department was expanded rapidly to meet the increasing demands on it, and at the date of the Armistice it employed 189 research chemists,

in addition to a large number of chemists who were giving part of their time to chemical warfare problems.

Laboratory researches on the offensive side were carried out mainly in the Universities, and we owe much to the professors and their assistants for their patriotic devotion to work which was never pleasant and usually involved considerable risks.

Field trials were carried out at an experimental station organised by Lieut.-Col. A. W. Crossley, C.M.G., F.R.S., where all appliances were tested in the various stages of their development. The tasks of the observers necessarily involved frequent exposure to dangerous concentrations of gas, and their gallantry and devotion to duty were important factors in the progress of the work and in the efficiency of the appliances sent to France.

The manufacturing situation was difficult owing to the lack of suitable plant and of technical resources. In April 1915 there was only one plant in the country producing liquid chlorine, with an output of seven tons a week. But the energy of the manufacturers enabled our first gas attack to be made in September 1915, and by December 31, 860 tons of gas had been sent to France. Subsequently the production increased continuously, the output of gas in each year being :—1915, 860 tons; 1916, 5,150 tons; 1917, 18,500 tons; 1918 (ten months), 15,500 tons.

Considering our unpreparedness, this was a fairly satisfactory result. But a comparison with the nature and amount of the German output, which was made possible by the peace resources of their dye factories, shows the necessity of developing our organic chemical industry, otherwise we may find ourselves at the mercy of any Power which has developed its resources in this direction and is prepared to take full advantage of them on the outbreak of war. The military value of the chemical industry is likely to be so great in the future that any country which dominates an important section of it, as Germany did before the war, is liable to become a standing menace to the peace of the world.

Defensive Research.

The defensive problems of gas warfare were of even greater importance than the offensive, for, although the nation which has the better gas possesses an advantage over its opponent, it is not necessarily overwhelming. While if troops are equipped with a respirator that fails to give protection in a gas attack, the situation of April 1915 is repeated and offers an opportunity that might easily be made decisive.

It is hard therefore to over-estimate the value of the work of the Anti-Gas Department under the direction first of Brigadier-General Sir William Horrocks, K.C.M.G., C.B., and afterwards of the late Lieut.-Col. E. F. Harrison, C.M.G., thanks to which our troops were always provided with adequate protection. Harrison was one of the great discoveries of the war. It is often stated that he was the inventor of the box respirator, but this he would have been the first to deny. His great merit was as an organiser. He gathered round him an enthusiastic group of young chemists and physicists, and the box respirator represents the joint result of their researches, carried out under his inspiration and controlled by his admirable practical judgment. He organised the manufacture of the respirator on a large scale, and it is a great testimony to his foresight and energy that in spite of all the difficulties of production the supplies promised to France never failed. Fifty-five million respirators were produced by the department, and of these nineteen million were box respirators.

Speed is essential in gas warfare either to avoid or to effect surprise, and it was fortunate that, so far as defensive appliances were concerned, research, design, inspection and manufacture were all under one department controlled by a man of Harrison's ability. If they had been separated delays would have been inevitable, and might have led to very serious consequences. The following incident illustrates both the need for rapid changes to meet possible developments, and for such flexibility of large-scale production as was made possible by the organisation of the Anti-Gas Department. A certain modification of the respirator was considered necessary in France, and officers were sent home to explain what was needed. Within forty-eight hours of their arrival arrangements

were made to modify the respirators, and within a few weeks the fighting troops had been re-equipped with the new pattern. Less than three months after the change had been recommended three attacks were made by the Germans which would certainly have had very serious consequences if our troops had not been in possession of the improved respirator, as the older pattern would not have withstood the concentration of gas employed.

This was only one of many changes that were made in the respirator to meet new developments, with the result that our troops always found themselves fully protected, and the confidence they placed in the respirator became an important factor in the success of our gas defence.

Development of the Respirator.

The respirator sent to France a few days after the first gas attack consisted of a pad of cotton wool which was to be dipped in a solution of sodium thiosulphate and sodium carbonate and held over the mouth. This was superseded in May 1915 by the 'black veil' respirator composed of a pad of cotton waste impregnated with the same solution, with the addition of glycerine, and enclosed in black veiling by which it could be tied over the mouth. By this means protection against a low concentration of chlorine was obtained for a short time, provided that the pad was carefully adjusted.

By the end of May the manufacture of the 'Hypo Helmet' was begun. This consisted of a flannel bag impregnated with a solution of sodium thiosulphate, sodium carbonate and glycerine, and provided with a small celluloid window. The bag was worn over the head and tucked in under the collar so that the inspired air was freed from chlorine by passing through the fabric. The protection, however, was limited to chlorine and strongly acid gases, and the 'P Helmet' was adopted for use in July 1915, and issued to the troops in August, in view of the possible employment of phosgene and hydrocyanic acid by the enemy. It was a bag similar to the 'Hypo Helmet,' made of flannelette impregnated with a solution of sodium phenate, sodium hydroxide and glycerine. In order to prevent the carbonation of the alkali by the passage of expired air through the fabric, the helmet was provided with a mouthpiece and rubber outlet valve through which air was exhaled, and it was consequently known sometimes as the 'Tube Helmet.' Phosgene was first employed by the enemy in the cloud attack on December 19, 1915, four months after the new helmet had been issued.

Early in 1916 it was thought necessary to increase the protection against phosgene in case clouds of higher concentration should be used, and the 'P.H. Helmet' was issued in February 1916, in which hexamethylene tetramine (hexamine) was added to the phenate solution. Hexamine reacts rapidly with phosgene, and the new helmet gave a greatly improved protection against this gas.

However, by this time the possibility of the employment of a wide range of chemical substances in gas warfare had been foreseen, and it was recognised that a more general type of protection was needed than that which could be obtained by means of a helmet impregnated with various solutions. The limitation of the helmet was seen in its failure to keep out lachrymatory gases such as xylyl bromide, in consequence of which the 'P.H.G. Helmet' was introduced shortly after the 'P.H. Helmet,' containing rubber sponge goggles to be worn over the eyes to protect them against any traces of lachrymator that might penetrate the helmet.

A large box respirator, giving a high degree of protection against all gases likely to be employed, had already been devised for the use of the Special Brigade, who always ran the risk of being exposed to high concentrations of gas when they were carrying out operations. This had to be reduced in size to make it suitable for general issue to the troops, and a satisfactory design was obtained in June, and issued to the troops in August, 1916. The respirator consisted originally of a metal container filled with layers of animal charcoal and of the soda-lime permanganate granules devised by Major Bertram Lambert at Oxford in June 1915, as an absorbent for chlorine, phosgene, hydrocyanic or other acids, and arsine. The container is carried in a haversack on the chest, and is connected by a corrugated rubber tube to a mouth-piece attached to a mask made of material impervious to gas and fitted with glass eyepieces. The mask is

held in position by elastic bands over the head so as to make an airtight joint round the face. The wearer breathes in and out through the mouthpiece, the nose being closed by a clip attached to the mask. Air is drawn in through an inlet valve at the bottom of the container, and any poisonous gas is absorbed during its passage through the charcoal and granules. The expired air passes out through an exit valve, the inlet valve closing in order to prevent expired air passing out through the container and causing deterioration of the contents.

The type of box respirator adopted by the Germans differs from ours, as the box containing the chemical absorbents is attached directly to the mask and no mouthpiece is used. The efficiency of the appliance depends therefore on the tightness of the joint between the face and the edge of the mask, and on the good condition of the latter material. If the mask does not fit the face or if it has been punctured, air containing gas passes direct to the lungs of the wearer and he becomes a casualty; whereas if the British mask is damaged the wearer continues to breath through the mouthpiece and tube, and he is safe except for the possible effect of the gas on his eyes. Also the British method of carrying the box of chemicals in a haversack on the chest, instead of attaching it directly to the mask, enabled us to use a larger box which gave a higher standard of protection, and it was a comparatively simple matter to add an extension to the British respirator if necessary. For instance, in April 1917 a small metal extension containing cotton wool was added at the bottom of each container to give increased protection against smoke particles such as those produced by the vaporisation of stannic chloride in air.

In August 1917 this extension was embodied in the improved 'N.C. Container' in which specially activated wood charcoal was substituted for animal charcoal, and layers of cellulose wadding added to stop smoke particles. The 'N.C. Container' continued in use until the Armistice, and its standard of protection was so high that there were no instances of men being gassed owing to the failure of a respirator which was in a serviceable condition. Whereas the earliest pad respirators only gave protection for a few minutes against concentration of chlorine of the order of one part in 10,000 parts of air, the 'N.C. Container,' when new, protects its wearer for half-an-hour or longer against one part of phosgene in 100 parts of air.

Work of the Gas Services.

In addition to the chemists who were working during the war in the research and supply departments and in the Special Brigade, a considerable number were employed in the various theatres of war and at home in advising commanders on technical matters connected with gas warfare, and in training and instructing the troops in gas defence. Their work, which was essential to our success in gas warfare, has not hitherto been generally known or appreciated. The problem of gas defence is not solved by devising a suitable respirator. It is necessary to train men very carefully in its use, and to give them sufficient information about the behaviour of gases, in order to make them understand the best methods of protecting themselves against gas, and to remove the ignorance which is the chief cause of their alarm. The instruction given at the many gas schools which were formed during the war was of vital importance in giving men confidence and in reducing the number of casualties, and enabled us gradually to reduce the disadvantage under which we suffered in consequence of the general lack of scientific training among all ranks.

In France the Chemical Advisers and Divisional Gas Officers had particularly responsible posts. In addition to their advisory and instructional duties, they played an important part in the organisation of the gas defence of their formations. It was their duty to investigate every enemy gas attack, to devise means of improving our defence, to collect blind gas shells for examination, and to collect evidence of the results of our own gas operations. All new appliances were sent to them for trial before they were adopted, and the rapid progress of our defensive measures would have been impossible without their criticism and advice, as they were in constant touch with front-line conditions, and could see how far the appliances were likely to meet present and future needs.

The organisation of the Gas Services in France enabled the use of any new gas by the enemy, the adoption of new gas tactics, or the occurrence of any new type of gas casualty to be investigated immediately, so that information could be sent rapidly to all parts of the front, thereby diminishing greatly the chances of a further surprise. As speed was of the utmost importance, a laboratory was organised at General Headquarters in April 1915 for the examination of enemy material and for the investigation of urgent problems that were met with in the field. The work of the Central Laboratory contributed greatly to the efficiency of the Gas Services, thanks to the mechanical ingenuity and the critical ability of the late Lieut.-Col. W. Watson, C.M.G., F.R.S., its first Director, and to the resourcefulness of his successor, Lieut.-Col. B. Mouat Jones, D.S.O., who was mainly responsible for the chemical investigations.

Thus in consequence of the introduction of gas in war, British chemists were called upon to perform the most varied duties and to face many difficult problems, which involved research in many new directions, the organisation of manufacture on a vast scale, and the instruction and training of the troops. To all those who took part in this work it must be a source of great satisfaction that, thanks to their efforts, not only were our forces protected against a very serious menace, but they were enabled to make effective reprisals against the enemy. The true measure of their success can be gauged by the general impression, confirmed by the statements of many German prisoners, both officers and men, that had the enemy foreseen the results of their treacherous use of gas in April 1915 the new weapon would never have been employed.

Report on Wave Motion.

By Sir G. Greenhill, F.R.S.

Part I.

(Ordered by the General Committee to be printed *in extenso*.)

Previous Reports to be consulted are by :—

Gerstner, *Theorie der Wellen*, Prague, 1804.
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O. Heaviside, Collected Papers, III., *Waves on Deep Water*.

And various mathematical papers in the *Proceedings of the Royal Society* and the *London Math. Society*, by Lord Kelvin, Lord Rayleigh, Burnside, Love, Macdonald, Hough, Havelock.

W. H. Wheeler, *Tides and Waves*, 1906.
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(These last two for fuller list of references.)

Report on Wave Motion in Water.

The waves may be divided into two classes :—

1. Surface waves, visible as moving waves or rollers (Atlantic), or stationary waves when seen reflected at a wall, or inside a tank, or along a pier or breakwater, important in harbour design.

2. Long flat tidal waves, propagated through the depth of the ocean, not revealed except in the tide of an estuary, past the shore, as in a ground swell.

For a visible representation of actual experimental wave motion of the surface of water, capable of numerical measurement, a deep rectangular tank may be employed, provided with a front wall of glass as in

an aquarium, say 2 feet 6 inches long by 3 feet deep, to make the water beat time with a half-second pendulum, taken as 10 inches long or 25 centimetres in round numbers, in a wave 5 feet long, double the length of the tank.

Placed on a lecture table this will be visible to the audience, to illustrate Lord Kelvin's definition of Wave Motion, as the passage of periodic motion through matter, in this case water or other liquid.

On a smaller scale, for mere illustrative action, any small vessel will serve, such as a basin, dish, tumbler, saucer, or water bottle of moderate size.

Colonel Russo, of the Italian Navy, has constructed an experimental tank where the motion of the water is kneaded by appropriate flexible diaphragms, and he shows the effect in a series of moving pictures, such as those he brought before the *Institution of Naval Architects*, 1916.

In our tank the walls are rigid, and, the water being initially at rest, the wave motion may be set up by a slight tilt of the vessel, or by a paddle passed through the water.

In the theoretical discussion the motion is supposed started by a variable impulse pressure applied suddenly over the surface; no motion would be set up if the pressure was uniform; and assuming the water incompressible and sound velocity through it practically infinite (really about 1,450 metres per second), this impulse pressure will be propagated instantaneously and uniformly down inside the water, and taken up with no reduction by the bottom and sides of the tank.

We may suppose this pressure applied as in the Humphrey pump by the explosion of a charge of petrol gas.

But any variation of the impulsive pressure over the free surface will set up an internal commotion, resulting in a wave motion of the water.

1. Take an origin O in the middle of the rectangular free surface of the water, and coordinate axes of reference, Ox, Oy, Oz; Ox vertically downward, Ox and Oy in the surface, Ox parallel to the length of the tank.

Suppose a variation of the applied mean uniform impulsive pressure A is given by the term B sin mx, so the total impulse over the surface is

$$\mathrm{A}+\mathrm{B}\sin mx,$$

with a wave length L, such that $m\mathrm{L}=2\pi$, but using m in the work for economy of printing. The term A is retained, so as to avoid the idea of a negative pressure, practically impossible.

When the tank length is half the wave length, $\frac{1}{2}\mathrm{L}$, a pure stationary half wave will be set up, as in Colonel Russo's experiments; and this is the longest wave in the tank, say 5 feet long.

The coefficient B will not remain uniform down in the water; it will be found on the theory of the Equation of Continuity that at a depth z it will have diminished to b, some function of z; and if the tank is deep enough for the motion to be insensible at the bottom, b dies out at compound discount with the depth z according to the law

$$b=\mathrm{B}e^{-mx}.$$

This with our tank 3 feet deep, and $z=3$, $\mathrm{L}=5$, $mz=\frac{6}{5}\pi$, say 3·7, $e^{-mx}=0{\cdot}025$, say 2·5 per cent. at the bottom, which we take as insensible.

A table in W. H. White's *Naval Architecture*, p. 197, gives a series of other values, based on taking $e^{\frac{2}{3}\pi}=2$, $e^{2\pi}=2^9=512$, very nearly, really 536.

$\frac{z}{L}$	0	$\frac{1}{9}$	$\frac{2}{9}$	$\frac{3}{9}$	$\frac{4}{9}$	$\frac{5}{9}$	$\frac{6}{9}$	$\frac{7}{9}$	$\frac{8}{9}$	1
e^{-mz}	1	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{32}$	$\frac{1}{64}$	$\frac{1}{128}$	$\frac{1}{256}$	$\frac{1}{512}$

A wave motion is set up by the variable impulse, in which the wave-length L in feet, the period T in seconds, and c the velocity of moving waves or rollers in feet per second (f/s), or K in knots, are connected on the subsequent theory by

(1) $$T=\sqrt{\frac{2\pi L}{g}}, \qquad c=\frac{L}{T}=\sqrt{\frac{gh}{2\pi}}.$$

For measurement in wave motion, the easiest quantity to observe is the period T, or its reciprocal when T is short, the number of waves in the second, or else the length l of the simple pendulum which beats $\frac{1}{2}$ T seconds, or revolves conically in T seconds; and then L and c can be determined from

(2) $$\frac{L}{T^2}=\frac{g}{2\pi}, \qquad l=\frac{gT^2}{4\pi^2}=\frac{L}{2\pi}, \qquad L=2\pi l.$$

Wave Length and Velocity.

2. For these rollers, surface waves advancing over water of practically unlimited depth, the landsman employs simple rules in his foot-second units, such as

(1) $$c=5t, \qquad c^2=5l, \qquad l=5t^2,$$

connecting the velocity c in f/s of surface waves of length l feet and period t seconds, over deep water.

Taking the formula $c^2=\frac{gl}{2\pi}$, this implies that $\frac{g}{2\pi}$ is replaced by 5 in round numbers instead of the more exact value 5·12, but within 2 per cent.

The sailor employs the cosmopolitan unit of the geographical or nautical mile, which he divides into 1,000 fathom, so that his fathom is 6 feet and a little over, say, 6·08 feet.

Then if R denotes the radius of the earth in nautical (N) miles, the circumference

$$2\pi R=360\times 60=21600, \text{ making } R=3438=\operatorname{cosec} 1',$$

the number of minutes is the radian.

He takes the hour as the unit of time and longitude, and his unit of velocity is the knot, a speed of 1 N mile/hour.

This makes the velocity of a point on the equator, due to the diurnal rotation, that is the velocity of the equilibrium tide at the equator,

$$21600 \div 24 = 900 \text{ knots.}$$

In these nautical units g would appear as an unfamiliar awkward number; so it is replaced by G, the velocity of a satellite grazing the equator 17 times a day, on the assumption that the pure g of gravity is diminished by one part in 289 by the centrifugal force of the diurnal rotation.

The period of the grazing satellite could also be deduced on Kepler's Law III, from the observed distance of the Moon, 60 semi-diameters of the earth, and its period of 27·3 days.

Then if the grazing satellite makes N circuits a day,

$$27{\cdot}3\mathrm{N} = (60)^{\frac{3}{2}}.$$

$$60 = \text{al } 1{\cdot}7782$$
$$60^{\frac{3}{2}} = \text{al } 2{\cdot}6673$$
$$27{\cdot}3 = \text{al } 1{\cdot}4367$$
$$\mathrm{N} = \text{al } 1{\cdot}2304 = 17.$$

At a distance one-9th of the Moon, with a lunar period taken as 27 days the period of the satellite would be one day, and the satellite would be stationary in the sky overhead, though moving with velocity 6,000 knots. The circumference of the Moon's orbit is $60 \times 21600 = 1{,}276{,}000$ miles, with velocity 2,000 knots.

The relative velocity of the Earth round the Sun is 60,000 knots, with the distance of the Sun 24,000 R, in a year of 360 days.

Turn the velocity of the grazing satellite vertically upward through a right angle and the body will reach a height R and return to the ground again in $\frac{\frac{1}{2}\pi+1}{\pi} = \frac{1}{2} + \frac{1}{\pi}$ of the period round the earth.

So, too, if the velocity of the moon was turned up through a right angle away from the earth, the moon will recede to a distance 120 R, and reach the surface of the earth again in $\frac{3}{4} + \frac{1}{2\pi}$ of the lunation.

These cosmopolitan numbers do not work out so well on the metric system, because sexagesimal time is always employed. Centesimal time, required for completeness in navigation and astronomy with centesimal angle, never came into use, as it would involve the destruction of the existing stock of clocks and watches, and the sailor sticks to sexagesimal time and longitude, and is not prepared to throw his chronometer into the sea, for the sake of a sentimental theory.

Thus $g = \frac{\mathrm{G}^2}{\mathrm{R}}$, in nautical units (knots an hour), where

$$\mathrm{G} = 17 \times 900 = 15{,}300 \text{ knots.}$$

Then for surface rollers over the ocean, L miles long, and period T hours, the velocity is K knots, given by

$$(2) \qquad K^2=\frac{gL}{2\pi}=\frac{G^2L}{2\pi R}=\frac{G^2L}{21600},$$

$$(3) \qquad L=KT, \qquad \frac{K}{T}=\frac{G^2}{2\pi R}.$$

With the period given in t seconds, $t=3600\,T$,

$$(4) \qquad \frac{K}{t}=\frac{3600\times 21600}{G^2}=\frac{3}{288}\left(\frac{G}{900}\right)^2,$$

making $K=3t$, if $17^2=289$ is replaced by 288, near enough on the accuracy of the numerical data; and then

$$(5) \qquad K=10800T, \qquad L=10800T^2, \qquad K^2=10800L.$$

Measuring the length of the wave by l feet, six to the fathom,

$$(6) \qquad K^2=\frac{10800}{6000}l=\frac{9}{5}l=1\cdot 8l.$$

For the long flat tidal waves through the depths of an ocean h fathom deep, the formula to employ is

$$(7) \qquad K^2=g\frac{h}{1000}=\frac{G^2}{R}\frac{h}{1000}, \text{ say } 68h,$$

with $$G=17\times 900, \quad R=3438, \quad \frac{1}{R}=\sin 1'=0{\cdot}00029,$$

$$(8) \qquad h=0{\cdot}0147K^2, \quad K=8{\cdot}25\sqrt{h}; \text{ or } K=G\sqrt{f},$$

for a depth the fraction f of the radius of the Earth.

Thence a table for ocean tidal waves, where the result is given to the nearest round number.

Depth in Fathom	Velocity in Knots	Time round the Equator in Hours
12,000 (12 miles)	900	24
3,000	450	48
1,900	360	60 (earthquake velocity)
750	225	96
200	120	180
144	100	216
4	16·5	—
1·5	10	—

Group Velocity.

3. Waves over the sea are not pure waves, but a blend of different wave lengths; just as white light is a blend of the monochromatic parts of the spectrum.

A simple pure wave of length λ, and period T, advancing with velocity V, is given by

$$(1) \qquad y = b \sin \frac{2\pi}{\lambda}(x - \mathrm{V}t) = b \sin (mx - nt),$$

writing m for $\frac{2\pi}{\lambda}$, and n for $\frac{2\mathrm{V}}{\lambda} = \frac{2\pi}{\mathrm{T}}$, for economy in space of printing.

This pure wave is replaced, in Stokes' explanation, by a blend of two such waves, nearly equal,

$$(2) \qquad y_1 = b_1 \sin (m_1 x - n_1 t + \epsilon_1), \qquad y_2 = b_2 \sin (m_2 x - n_2 t + \epsilon_2).$$

Their resultant, at the same time, t, and same place, x, is given by

$$(3) \qquad y_1 + y_2 = \tfrac{1}{2}(b_1 \pm b_2)\,[\sin (m_1 x - n_1 t + \epsilon_1) \pm \sin (m_2 x - n_2 t + \epsilon_2)]$$

$$= (b_1 \pm b_2) \begin{matrix} \cos \\ \sin \end{matrix} \tfrac{1}{2}[(m_1 - m_2)\,x - (n_1 - n_2)\,t + \epsilon_1 - \epsilon_2]$$

$$\begin{matrix} \sin \\ \cos \end{matrix} \tfrac{1}{2}[(m_1 + m_2)\,x - (n_1 + n_2)\,t + \epsilon_1 + \epsilon_2]$$

of which the second factor represents a wave of length

$$\lambda = \frac{2\pi}{m_1 + m_2} = \frac{2}{\frac{1}{\lambda_1} + \frac{1}{\lambda_2}},$$

the harmonic means of the wave lengths λ_1 and λ_2, moving with velocity

$$(4) \qquad \frac{n_1 + n_2}{m_1 + m_2} = \frac{\frac{\mathrm{V}_1}{\lambda_1} + \frac{\mathrm{V}_2}{\lambda_2}}{\frac{1}{\lambda_1} + \frac{1}{\lambda_2}},$$

and when the two waves are nearly equal, this is equivalent to the pure wave motion of (1), with $\mathrm{V}_1 = \mathrm{V}_2 = \mathrm{V}$, $\lambda_1 = \lambda_2 = \lambda$.

The first factor represents a wave motion of long period T and great length L, the equivalent of Scott Russell's primary solitary wave, in which

$$(5) \qquad \frac{2\pi}{\mathrm{T}} = \frac{1}{2}(n_1 - n_2) = \pi \left(\frac{\mathrm{V}_1}{\lambda_1} - \frac{\mathrm{V}_2}{\lambda_2}\right), \qquad \frac{2\pi}{\mathrm{L}} = \frac{1}{2}(m_1 - m_2) = \pi \left(\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right)$$

advancing with velocity

$$(6) \qquad \mathrm{G} = \frac{n_1 - n_2}{m_1 - m_2} = \frac{\frac{\mathrm{V}_1}{\lambda_1} - \frac{\mathrm{V}_2}{\lambda_2}}{\frac{1}{\lambda_1} - \frac{1}{\lambda_2}}$$

and this is the *group velocity*, when the wave length, λ_1 and λ_2, and velocity, V_1 and V_2, is so nearly equal, that we take

$$(7) \qquad G=\frac{dn}{dm}=\frac{d\frac{V}{\lambda}}{d\frac{1}{\lambda}}=V-\frac{dV}{d\lambda}:$$

and $\frac{n}{2\pi}$ is the number of waves per unit of time, $\frac{m}{2\pi}$ is the number of waves per unit of length.

The effect is to make the amplitude of rise and fall at one spot to diminish, and then increase again, in the long period T.

This is observed when we follow with the eye the crest of a particular wave of the sea. After a maximum height, it is seen to die down gradually, and meanwhile another wave has been growing up behind it.

Group velocity of sea waves was known to the sailor of all time, in his proverbial formula of every tenth or third wave a big one, δεκακυμία or τρικυμία, according to the fetch of the sea, great or small, across the Ionian or inside the Ægean.

Ovid records it on his voyage into exile across the Ionian Sea.

> "Qui venit hic fluctus, fluctus supereminet omnes,
> Posterior nono est, undecimoque prior."
> "Vastius insurgens decimæ ruit impetus undae."

Thus in sea rollers, where λ varies as V^2, if every nth wave is a big one, between the $n-1$ and $n+1$th (Ovid's nine and eleven, with $n=10$),

$$(8) \qquad G=\frac{\frac{V_{n-1}}{\lambda_{n-1}}-\frac{V_{n-1}}{\lambda_{n-1}}}{\frac{1}{\lambda_{n-1}}-\frac{1}{\lambda_{n-1}}}=\frac{\frac{1}{V_{n-1}}-\frac{1}{V_{n-1}}}{\frac{1}{V_{n-1}^2}-\frac{1}{V_{n-1}^2}}=\frac{1}{\frac{1}{V_{n-1}}+\frac{1}{V_{n-1}}}$$

half the harmonic means of V_{n-1} and V_{n+1}.

When V is assumed to vary as some power, q, of λ,

$$(9) \qquad \frac{dV}{d\lambda}=q\frac{V}{\lambda},\ G=(1-q)\ V.$$

Thus in deep water waves, rollers over the sea, when the velocity varies as the square root of the length, $q=\frac{1}{2}$, $G=\frac{1}{2}V$.

In short capillary waves, Scott Russell's tertiary waves, produced by drawing the point of a stick through water, $q=-\frac{1}{2}$, as also in the waves of lateral vibration of a bar, and then $G=\frac{3}{2}T$, and the group velocity is not observed, except when a stone is thrown into water, in the dark streaks of reflexion seen overtaking the capillary waves.

In his Report on Waves to the British Association, 1844, Scott Russell quotes Homer's simile, of the waves on a cornfield as well as the sea (Iliad II 144, XX 227), imitated by Shelley, but incorrectly, in

> 'the ripe corn under the undulating air undulates like an ocean.'

But here each cornstalk vibrates or undulates independently in the

same period, like Osborne Reynolds' series of independent pendulums, so that V varies as λ, $q=1$, $G=0$; and the appearance is explained of the stationary patches in the waves of the cornfield in a wind, compared by Homer to the stage crowd of the public assembly in the market-place.

Echelon Waves.

4. These waves have been described and illustrated by W. Froude (*Trans. Institution of Naval Architects*, I.N.A., 1877), and an explanation was given by Sir W. Thomson, reprinted in his *Popular Lectures*; also by R. E. Froude, on Ship Resistance (*Greenock Philosophical Society*, 1894), and Hovgaard (I.N.A., 1909).

They are seen stretching aft from the bow wave in a line of echelon, and at sea on a calm day they can be watched from the deck of a steamer till they disappear over the horizon, sifted out as pure waves with no group velocity effect. On a small scale the wake of a duck will exhibit the echelon waves quite clearly, or of a stick drawn through the water.

The effect is explained by a combination of interference and group velocity; the following geometrical construction is submitted to replace previous long analytical calculations.

The bow wave is thrown off in a hump at O in fig. 1, with the crest OE at an angle θ with the beam, and it is followed by the next wave BC, thrown off at B on the side OB of the ship.

Looking along BC, a hump is seen at C on the wave, and this is followed by a series of equidistant humps on the line OC, showing a series of waves following the ship in echelon, but with the crest parallel to the bow wave at O; the problem is to calculate the angle ϕ which OC makes with the beam.

The perpendicular OA on BC is the wave length λ, between the parallel crests OE, BC; and representing the speed of the ship, K knots, by the vector OK, and drawing KV perpendicular to AO produced, then OV is the vector representing the wave velocity, V knots.

The hump at C is produced by the interference of the wave A′C, of slightly different length OA′, $\lambda+d\lambda$, and velocity OV′, $V+dV$, at a small angle AOA′; and then in the figure

$$(1) \qquad \frac{VK}{AC}=\frac{Vv}{Aa}=\frac{dV}{d\lambda} \quad \frac{AB}{VK}=\frac{OA}{OV}=\frac{\lambda}{V};$$

and drawing OF perpendicular to OA,

$$(2) \qquad \frac{AB}{AC}=\frac{OE}{OF}=\frac{\lambda}{V}\frac{dV}{d\lambda}, \quad \frac{BC}{OF}=1-\frac{\lambda}{V}\frac{dV}{d\lambda}=\frac{G}{V},$$

G denoting the group velocity of the waves.

When V varies as the qth power of λ,

$$(3) \qquad G=(1-q)\,V,$$

$$(4) \qquad \frac{AB}{AC}=\frac{AB}{AO}\frac{AO}{AC}=\tan\theta\tan(\phi-\theta)=\frac{\lambda}{V}\frac{dV}{d\lambda}=q$$

Thus, in deep-water waves, where

(5) $$V=\sqrt{\frac{g\lambda}{q\pi}}, \quad q=\tfrac{1}{2}, \quad G=\tfrac{1}{2}V, \quad BC=\tfrac{1}{2}OF=OE.$$

In short capillary waves, seen round the stem, $q=-\frac{1}{2}$, and no echelon waves are discernible.

Sound waves in air are propagated with the same velocity for all wave lengths, otherwise music would be impossible and could not exist;

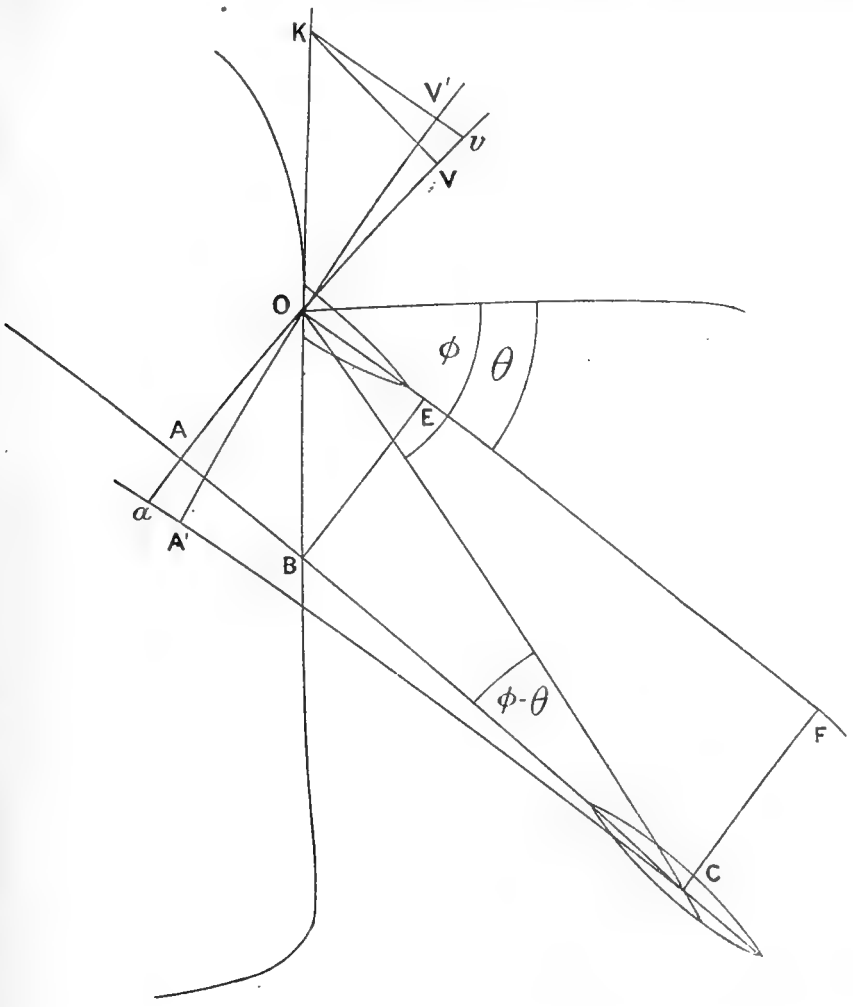

FIG. 1.

the $q=0$, $\phi=\theta$, and the echelon waves are merged in the wave front. This is revealed in the bullet photograph, where the bow and stem wave are taken very clear and distinct in the air. With the very sharp point of the new bullet, the head is seen penetrating the bow wave, as on the sharp bow of a steamer.

5. Sound waves are due to vibration of the air, propagated with velocity about 1100, f/s, and generated for music by a vibrating body, such as a violin string, a piano wire, the voice, or an organ pipe (fig. 1).

The motion is visible in a taut cord or chain, as a rope, hawser, or cable, and it is realised experimentally with ease in this way, for theoretical illustration, not requiring the complication of a tank of water.

An elementary and exact treatment can be submitted, where the motion is not restricted to be small, if the wave motion in the rope is helical, and appears progressive, each particle whirling round the axis in a circle with the same velocity, linear and angular.

A stiff wire, wound into some convolutions of a uniform helix, is useful in elementary explanation. Suspended vertically from a point in its axis and revolved, the advance of the waves is seen in the helix, as well as in the shadow on a wall or the floor.

Take a half length, $\frac{1}{2}$L, measured axially, of a helical wave of the equivalent flexible rope, wound on a cylinder of radius b, so that if α is the angle of the helix with the axis, $2\pi b = \mathrm{L} \tan \alpha$.

Suppose the rope weighs w, lb/ft, and is stretched to a tension or pull P, lb, so that $h = \frac{\mathrm{P}}{w}$, called the *tension length*, is the length of rope hanging vertically to produce tension P.

Projected on a plane perpendicular to the axis, the half wave appears as a semicircle, of line density $\frac{w}{\sin \alpha}$, lb/ft; and it is in equilibrium under the transverse component tension P sin α at each end, and the centrifugal force (C.F.) of the rotation n, radians/second, equivalent to an internal pressure $\frac{w}{\sin \alpha} \cdot \frac{n^2 b}{g} = \frac{w}{\sin \alpha} \cdot \frac{b}{l}$, lb/ft, acting radially over the semicircle, putting $g = ln^2$, so that l is the height of the equivalent conical pendulum.

The resultant C.F. thrust over the semicircle is the same as the thrust over the diameter, $2b$, due to the same pressure, and so is $\frac{w}{\sin \alpha} \frac{n^2 b}{g} 2b$; so that for equilibrium

$$2\mathrm{P} \sin \alpha = \frac{w}{\sin \alpha} \frac{n^2 b}{g} 2b, \tag{1}$$

$$h \sin^2 \alpha = \frac{n^2 b^2}{g} = \frac{n^2}{g} \left(\frac{\mathrm{L}}{2\pi} \right)^2 \tan^2 \alpha,$$

$$\frac{gh}{n^2} \cos^2 \alpha = lh \cos^2 \alpha = \left(\frac{\mathrm{L}}{2\pi} \right)^2. \tag{2}$$

Denoting by λ the length of rope for one radian angle of turn, $\frac{\mathrm{L}}{2\pi} = \lambda \cos \alpha$, the relation reduces to the simple form

$$lh = \lambda^2. \tag{3}$$

In the period of revolution, $T=\frac{2\pi}{n}$, the wave advances L, and so with velocity $c=\frac{L}{T}=\frac{nL}{2\pi}=nl$, thus

(4) $$c^2=gh\cos^2\alpha, \text{ reducing to } c^2=gh,$$

when the rope is taut, and $\alpha=0$, as in the usual elementary theory.

If the stiff helical wire is passed through a corkscrew hole, like a screw through a fixed nut, the helix advances as it turns, and passes through its own shape, so as to appear stationary as a fixed curve.

In the flexible rope of the same shape, the velocity of advance is c, and the velocity of the helix through the nut is $v=c\sec\alpha$, so that the relation above becomes $v^2=gh$. This is in accordance with the general result for any flexible rope or chain, of any invariable shape through which it is passing with tangential velocity $v=\sqrt{(gh)}$; seen sometimes in heaving the lead, or in the helical curve of the life-line drawn out by the life-saving rocket of the coastguard.

With the axis of the helix horizontal and passing perpendicularly through a nut in the wall, or else with the helix revolving about the axis, the projection shadow thrown on the wall by a horizontal ray aslant is a trochoid, fixed or moving, visual realisation of Rankine's trochoidal wave, stationary or advancing.

The shadow thrown by rays at right angles to the axis will be a sinusoid; but this cannot represent a wave motion of the rope unless the curve is very flat.

6. To give an elementary demonstration of the condition of a stationary wave, revolving bodily, as on a musical cord fixed at the ends, the method must be restricted to the taut chain, of length $a=\frac{1}{2}L$, displaced into a flat sine curve, taken as given by

(1) $$y=b\sin mx, \qquad mL=2\pi,$$

with a slope mb at each end; and the $2Pmb$ balances the C . F.

The average value of y in the half wave is $\frac{b}{\frac{1}{2}\pi}$, so that the C . F. is

(2) $$w\frac{n^2}{g}\tfrac{1}{2}L\frac{b}{\frac{1}{2}\pi}=2Pmb, \qquad \frac{wn^2}{gm}=Pm,$$

(3) $$gh=g\frac{P}{w}=\frac{n^2}{m^2}=\frac{L^2}{T^2}=c^2,$$

as before; and the number of revolutions, cycles, or double vibrations per second, is

(4) $$\frac{1}{T}=\frac{n}{2\pi}=\sqrt{\frac{gh}{L^2}}=\sqrt{\frac{gh}{4a^2}}.$$

For a revolving slack chain, such as a skipping rope, the curve would be given by the elliptic function

(5) $$g=b\,\mathrm{sn}\,mx.$$

To realise a plane sine curve of finite amplitude, the rope would require to be of variable linear density, such that the axial distribution of density was uniform.

The velocity $c=\sqrt{(gh)}$ is that acquired in falling freely under gravity through $\frac{1}{2}h$, half the tension length, analogous to long flat tidal waves in water of depth h. But in surface waves, rolling over deep water, $c=\sqrt{\frac{gh}{2\pi}}=\sqrt{gl}$, where l is the equivalent conical pendulum length.

Other physical results may be stated in a similar manner.

Thus the velocity of longitudinal waves in an elastic cylindrical rod is due to half the elastic length k, where the length ek hanging vertically will produce extension e, provided the tension is under the elastic limit, so that e is small.

And the bursting velocity of the rim of a flywheel, treated as a circular wire filament, is due to half the tensile breaking length of the material.

A comparison is made between the waves of vibration of a taut hawser or piano wire, and the slack helical waves, or the plane waves of finite amplitude seen in laying a cloth or shaking a blanket, or heaving the lead, and firing a life-line rocket.

7. Tie a knot on the chain, to represent a weight attached, and investigate in this way the reflected and transmitted wave, and the mechanical illustration of the Pupin coil on a telephone wire.

Suppose the knot or weight is the equivalent of a length a of the chain, of line density σ, stretched to a tension P, and represent the incident, transmitted, and reflected waves by

(1) $y=b\sin(nt+mx)$, $y_1=b_1\sin(nt+mx-\epsilon_1)$, $y_2=b_2\sin(nt-m_2-\epsilon_2)$.

The geometrical condition at the weight, $x=0$, is

(2) $$y+y_2=y_1,\ b\sin nt-b_1\sin(nt-\epsilon_1)+b_2\sin(nt-\epsilon_2)=0,$$

for all values of t; so equating to zero the coefficients of sin nt and cos nt,

(3) $$b-b_1\cos\epsilon_1+b_2\cos\epsilon_2=0,\ b\sin\epsilon_1-b_2\sin\epsilon_2=0.$$

The dynamical equation of the weight at $x=0$ is, in gravitation units,

(4) $$\mathrm{P}\frac{dy}{dx}-\mathrm{P}\frac{dy_1}{dx}+\mathrm{P}\frac{dy_2}{dx}-\sigma a\frac{d^2y_1}{g\,dt^2}=0,\ \text{with}\ \frac{n^2}{m^2}=\frac{g\mathrm{P}}{\sigma},$$

leading to

(5) $$b\cos nt-b_1\cos(nt-\epsilon_1)-b_2\cos(nt-\epsilon_2)+mab_1\sin(nt-\epsilon_1)=0,$$

(6) $$b-b_1\cos\epsilon_1-b_2\cos\epsilon_2-mab_1\sin\epsilon_1=0,$$

(7) $$-b_1\sin\epsilon_1-b_2\sin\epsilon_2+mab_1\cos\epsilon_1=0.$$

Thence from these equations

(8) $$\tfrac{1}{2}ma=\tan\epsilon_1=-\cot\epsilon_2,\qquad \epsilon_2=\tfrac{1}{2}\pi+\epsilon_1,$$
$$b_1=b\cos\epsilon_1,\qquad b_2=b\sin\epsilon_1.$$

(9) $$y_1=b\cos\epsilon_1\sin(nt+mn-\epsilon_1).$$

(10) $$y+y_2=2b\sin mx\cos nt+b\cos\epsilon_1(\cos nt-mx+\epsilon_1).$$

Fasten the chain at two points A, B in the same horizontal line, $OA=c, OB=c_1$, and revolve the weight and chain round bodily, in steady motion, to imitate a transversal vibration.

The chain being taut, at tension $P=\sigma h$,

$$(11)\quad h\frac{d^2y}{dx^2}=-\frac{y}{l}, \qquad y=b\sin\frac{c-x}{\sqrt{(lh)}}, \qquad y_1=b_1\sin\frac{c_1+x}{\sqrt{(lh)}},$$

and at

$$x=0, \qquad y=y_1, \qquad b\sin\frac{c}{\sqrt{lh}}=b_1\sin\frac{c_1}{\sqrt{lh}}.$$

At the weight

$$(12)\qquad P\frac{dy}{dx}-P\frac{dy_1}{dx}+\sigma a\frac{y}{l}=0,$$

leading to the condition

$$(13)\qquad \cot\frac{c}{\sqrt{(lh)}}+\cot\frac{c_1}{\sqrt{(lh)}}=\frac{\sigma a}{P}\sqrt{\frac{h}{l}}=\frac{n^2a\sqrt{(lh)}}{V^2},$$

with V the wave velocity along the chain,

$$(14)\qquad \frac{\sigma}{p}=\frac{g}{V^2}=\frac{n^2l}{V^2}.$$

(To be continued.)

EVENING DISCOURSES.

THURSDAY, SEPTEMBER 11.

The Palace of Minos and the Prehistoric Civilisation of Crete. *By* Sir ARTHUR EVANS, *F.R.S.*

Civilisation might perhaps be defined as a social condition inherited from long experience of life in an ordered State. Our own civilisation was in a principal degree taken over from the Greco-Roman. It came in a direct line from Ancient Greece, together with elements taken as we know from Semitic and other Oriental sources. But how did the highly developed civilisation of Ancient Greece itself, on which our own is based, come into being? Was it indeed an exception to all rules, a kind of *Enfant de Miracle*? Such till lately was the tacitly accepted view. A rude shock to this complacent assumption was indeed given by Schliemann's discoveries at Mycenae, but even the finest of these were explained away as due to 'oriental' derivation. Still, the earliest traditions of Greece were not at fault on the matter. They pointed consistently to Crete for the source of Greek civilisation. There Minos had founded his great sea Empire, there in 'broad Knossos' his craftsman Daedalos had built him a marvellous palace. There, on the sacred mountain from the hands of its God—like Moses—he had received the law. The other mythical stories are well known. The palace became a Labyrinth, where dwelt the Minotaur, half man half bull and devoured the captive children, till Queen Ariadne—in whom an old Cretan Goddess is thinly disguised—supplied the clue to her champion, Theseus, who slew the monster and delivered his victims.

Well, it has nearly all come true. Visiting the island first in 1895, and the subsequent year, I made preliminary investigations with a view of attacking the problem of its pre-history. At Knossos itself—the fabled site of the 'Palace of Minos'—where an early wall and magazine had already come to light, I obtained on the spot a variety of evidence—including the actual indication of a prehistoric system of writing—which encouraged me to make every possible effort to carry out excavation there. But, though in the year of this first visit I secured the actual proprietorship of a part of the site, the difficulties of the times were such that it was not till 1900 that it was possible to begin excavation there. Its results have shown that the old tradition was essentially true, In successive years the spade brought out the remains of a great palace, rich beyond all expectation in treasures of art and culture—including whole archives of written documents—and unfolding in fact an early European civilisation going back two thousand years before that of Hellas. The immense amount of materials brought to light has made it impossible to publish any full account of the discoveries. Supplementary researches made in 1913 put me at last in the position to attempt a general view of the results in a collective work on the 'Palace of Minos,' but the difficulties caused by the War have delayed its publication, and it is as much as I can hope to bring out the first volume before the end of this year.

The materials brought out at Knossos have been supplemented by other rich finds made by my colleagues of the British School at Athens and of the Italian Mission, in various parts of the island. A whole new vista of early civilisation has opened out, involving an entirely new classification as a preliminary to its scientific treatment. At a former meeting of the Association I had the honour of

laying before it a preliminary scheme for such a classification. I ventured to give the culture as a whole the name of 'Minoan,' and divided its whole extent into three main Ages, the 'Early,' 'Middle,' and 'Late,' each in turn subdivided into three Periods. I am glad to say that this system, which I have since been able to elaborate further, together with the name of 'Minoan,' has now received a general acceptance in this country, on the Continent, and in America.

It is, of course, on this occasion only possible to give a very brief and fragmentary conspectus by means of lantern slides, but some of these may have a special interest as representing results and restorations only now arrived at after many years of work in which I have received the greatest assistance from my collaborators, Dr. Mackenzie, the two architects of the excavation, Mr. Theodore Fyfe, and Mr. Christian Doll, and from many other fellow-workers.

As a preliminary to the remains of the Minoan Age proper a section was shown of the Neolithic Strata, going down nine metres below the Palace at Knossos, and displaying characteristics which enable it to be subdivided into Upper, Middle, and Lower Neolithic stages. An extraordinary family of clay female idols brought to light from these deposits must be recognised as prototypes of a Cretan Mother Goddess, and wide oriental parallels to these figures were passed in review.

In illustrating the '*Early Minoan Age*' (c. 3500-4000) an overwhelming mass of evidence was adduced demonstrating connections with Egypt from the late prehistoric Period onwards. Among the proofs of this was the discovery at Knossos of imported diorite and syenite vases of the early dynasties, together with their Cretan imitations. Egyptian seals and copper vessels were also shown to have been copied. For the first time a direct connection of the earliest European civilisation with that of the Nile Valley was thus established. Specimens were also shown of beautiful Early Minoan gold work, some of it distantly foreshadowing that of Mycenae.

The '*Middle Minoan Age*,' dating from c 2200 to 1580 B.C. was roughly contemporary with the Middle Kingdom in Egypt, and gave evidence of continued inter-relations. An Egyptian Twelfth Dynasty monument was actually found in the Palace. It is from the beginning of this Period that the foundation of the existing Palace dates. Towards its close a great restoration took place to which the Domestic Quarter of the Palace belongs—with its grand staircase and halls and modern sanitary arrangements. Illustrations were given of the fine polychrome ceramic art of this Age, and of the marvellous 'egg-shell' pottery, Much of it was shown to imitate vessels in precious metals, the prototypes of those of the Mycenae graves. Proof was afforded of a curious link with the Libyan shores, the use of ostrich egg vessels for libations from which orginated a whole family of clay and stone forms. Lantern slides were also exhibited illustrating the earlier class of Fresco paintings and the beautiful faience figures found in the shrine of the Snake Goddess.

The '*Late Minoan Age*' from c. 1580 presents in its earlier phase the acme of naturalism in art, of which examples were given in the high reliefs of painted stucco, belonging to agonistic and bull-grappling scenes. Further illustrations were shown in an ivory figure of a 'taureador' and a stone vessel in the form of an ox's head. To this time belonged the most developed form of linear script, of which several documents were reproduced. The extraordinary modern style of the civilisation appears from the miniature frescoes of the Court ladies and restorations were given, warranted in almost all details by the existing remains of the 'Room of the Throne' and the Queen's Chamber or 'Megaron,' with the frescoes on the walls. The constantly recurring bull-grappling scenes remains of which, in painted stucco, were found by the North Gate, and a maze pattern, that had covered the walls of a corridor by the Water Gate of the Palace, helped to explain the actual genesis of the old stories of the Minotaur and Labyrinth.

FRIDAY, SEPTEMBER 12.

The Gyroscope Compass. *By* SIDNEY G. BROWN, *F.R.S.*

THE lecturer spoke at some length of the magnetic or mariner's compass, showing its construction; on the variation; on secular changes in the earth's magnetism; on changes in the ship's magnetism during a voyage; on the weak directive action of the earth which was further very greatly reduced in an iron ship; on the necessary corrections and their insufficiency; on the damping of vibrations which caused the compass to go round with the ship so that the course was sinuous and the length of a passage lengthened even with the most careful steering. Even in a calm sea the ship often headed seven degrees on either side of the true course. A magnetic compass was of no use in a submarine. He showed a *new phenomenon*, that a magnetic compass of very slow period, supported on gymbals, even when the dynamic balance recommended by Evans and Smith in 1881 (Phil. Trans.) was perfect, might go greatly wrong if it had a wobbling motion such as may be produced on a rolling, pitching ship, and is quite common on an aeroplane. This was explainable mathematically; what good mathematicians had not yet explained but what he would vouch for as a fact, was that if the compass were carried round in a horizontal circle without wobbling, the same and even more curious errors took place.

In an experiment here he showed a body free to rotate about a vertical axis; the lecturer gave a small rotation to the body, and asked the audience to observe that it would continue to rotate during the whole time of the lecture. He said he had proved that the solid friction was nearly infinitely small. It was this kind of support that made it possible to get an accurate gyro-compass, and he would describe it later.

To illustrate some gyroscopic phenomena experimentally, the lecturer used a case in which a 4-inch wheel, weighing $4\frac{1}{4}$ pounds, was revolving at 15,000 revolutions per minute, the same as he used in the gyro-compasses which were exhibited and would be described. The wheel was kept rotating at constant speed by a three-phase electric motor fixed inside the case. The rotating part was therefore not touched by brushes. The three-phase currents came from a small motor-generator fed from ordinary electric light mains, the current being steadied by a set of small accumulators. As being necessary for the simple explanation of the compass, later, he made it clear that when the axis of the wheel was free to turn in azimuth, a weight which tended to tilt the axis did not tilt the axis but caused the axis to precess in azimuth; whereas a force tending to turn the axis in azimuth did not do so but altered the tilt. If the axis of the wheel is kept horizontal but is free to turn about a vertical axis, as the earth is continually tilting the axis of the wheel in space, this axis precesses until in the N.S. direction. When in this direction the rotation of the earth no longer tilts the axis or causes motion in azimuth. Vibrations were well damped so that this compass having been displaced several times returned quickly to the north every time. This proof of the earth's rotation was first described by Foucault fifty-five years ago. It is an experiment which has never succeeded before in front of an audience because, until now, there has never been a free frictionless vertical support for a heavy body. The lecturer said that when this compass pointed east and west the directive action of the earth was so small a force as to be only the weight of one grain with a leverage of 12 inches. When the compass pointed one degree from the north the directive action was only one grain with a leverage of one-fifth of an inch. Left to itself in any position this heavy compass, weighing altogether about 7 lb., reached the north in about one minute, and seemed to be right with a probable error of one-tenth of one degree.

Such a compass would be of service on land, but on a ship it needs to be carried like a *pendulum* on gymbals, and its periodic time of vibration is greatly lengthened. The rotation of the earth does not now act directly on the gyro wheel but through gravity, by means of the pendulous weight.

The lecturer spent some time in giving a popular explanation of what occurs, but it cannot be given in a short abstract. If at any instant the angle of tilt is T and the deflection from the north is A, the above experiment shows that

the effect of pendulum gravitation which is proportional to T produces a precession proportional to T, and the earth's directive action which is proportional to A produces a rate of decrease of T which is proportional to A. The result is a *vibratory* motion. We find that T is usually very small compared with A. We find that A is at the end of its swing when T is zero and *vice versa*. A is alternately west and east of north. Now it is necessary that the compass should get to the north in diminishing swings and come to rest there; that is, the swings must be *damped*. We cannot directly damp the azimuthal motion, because as in the magnetic compass of our Navy the support and damping medium are carried round by the ship. Anschütz, in his early form of compass, by the use of an air blast gets rid of this connection with the ship. The air blast was arranged to oppose the movement in azimuth when the wheel tilted, and thus he obtained good damping. The strength of the air blast which varies proportionately to the tilt should be nothing when the compass is at rest on the north, that is when the tilt is nothing, and this would be true with the compass at the equator. In other latitudes, however, the compass sets itself with a tilt still remaining. The wheel has a tilt because it is trying to set itself due north, and this leaves a residual air blast producing a constant error in azimuth. There is always this *latitude error* if we introduce forces in azimuth proportional to the tilt. It is therefore preferable to damp the swings by acting on the tilt motion, because in this case there will be no latitude error. How this is done will be described later. There are three forms of gyro-compass now in use. The Auschütz (German), the Sperry (American), the Brown (British).

In the Anschütz the instrument is supported by a bath of mercury (as originally suggested by Lord Kelvin). There is a quasi-solid friction about the vertical axis, however clean the mercury may be, and this introduces error. In the 'Sperry' the gyro is supported by a wire, the twist when it occurs being taken out by a 'follow-up' motor through an electric contact which switches on the current to the motor. In the 'Brown' the lower end of the vertical spindle acts as the ram of a pump and stands upon a column of oil. The oil is under great pressure (some 500 lb. to the square inch), and is kept pumping up and down, and thus raising and lowering the vertical axis continually, some 180 times per minute. The continual movement of the spindle results in a vertical support which has an inconceivably small amount of solid friction. A ship has an angular motion of one revolution in one day. If she sails north at, say, 20 knots, she has another angular motion of one revolution in forty-five days. A gyro-compass on the ship is sensible of both these angular motions, and sets itself to make a compromise between them, and so points, not to the true north, but one or more degrees west of the true north; this deviation is the *north steaming error*. Knowing the latitude and north speed of the ship we have tables to allow for this error, and a special form of repeater was exhibited by Brown in which the card can be set eccentrically so that the correction may be automatically applied without further reference to the tables. Acceleration or change of north speed will have another effect on the compass, as it acts on the pendulous weight, and so starts an oscillation which may be called the *ballistic error*.

A little mathematics shows that if the period of the compass is eighty-five minutes, the compass takes its new position without oscillation, or, as we say, as if it were *dead beat*, and there is no ballistic error. But in actual practice it is found that when a ship turns in its course, and especially when it describes a quadrant or semi-circle, an oscillation is set up in any gyro-compass. Mr. Brown discovered this to be due to the methods of damping employed, and mathematics shows that this is the case. This he calls the *damping error*. That this error is due to damping and may therefore be got rid of in a simple way was now published for the first time. On a merchant ship the damping error is of little moment, but in a war vessel which is manœuvring it may be serious, as it may swing the compass off its correct reading by several degrees.

Mr. Brown said that his difficulties had been endless. As soon as he had what he thought to be a perfect compass an error would be discovered, and months or years were spent in correcting it. The other inventors, who were more or less satisfied with their own results, had no doubt met with the same difficulties, but these errors were unknown not merely to new inventors but even to

Admiralty compass experts in all countries. The lecturer considered that he was doing general good, and was not doing himself much harm in disclosing the knowledge he had spent so much time and money in obtaining.

The greatest of these errors was what he called the *quadrantal error*; its elimination has had more to do with drastic changes of design in all forms of gyro-compass than anything else. When a ship's course is neither N. nor S. nor W. nor E., but between these directions, and particularly N.W. or N.E. or S.W. or S.E., and if she rolls steadily, the compass gradually gets away from the north, setting itself sometimes with an error of 20°. Mr. Brown's popular explanation of this phenomenon and its remedy are too long for an abstract. They may be briefly put as follows: It has long been known (see Evans and Smith, 1881, Phil. Trans.) that to avoid this error there must be dynamic balance (that is the moment of inertia A of the gyro about OA, the axis of the wheel, must be equal to the moment of inertia B about OB, a horizontal axis at right angles to the first).[1] Auschütz certainly knew this in 1911, but he tried in vain to get dynamic balance, and his use of many gyroscopes in one compass was an attempt to get round the difficulty, but it resulted in great complexity. Mr. Brown saw that it was impossible to get dynamic balance, because although B was fixed and definite, A depended upon the rate of rolling of the ship. If there were absolutely no friction at the pivots of the wheel the inertia of the wheel would form no part of A and balance would be possible, but there is always some such friction, and the inertia of the wheel is more or less added to A, so that A is variable and its balance is impossible. But a careful study of terms usually neglected in the mathematical theory showed that whatever A and B might be, there would be no quadrantal error if the vibratory angular motion about OA could be made to differ in phase from the motion about OB by a quarter period. Before he had a mathematical reason for this he had constructed a form of gyro-compass quite different from what he had hitherto been trying, and by intuition and good fortune he found that it had no quadrantal error. Later, he found that it fulfilled this mathematical condition. But the intuition and success came before the mathematics. It is always wise, however, to get as good dynamic balance as possible by a symmetrical disposition of masses, and also to minimise both the angular motions. This discovery of the cause of the quadrantal error and its correction are here made public for the first time.

Besides well-known simple apparatus, Mr. Brown exhibited his *master compass* which had been turned quite away from the north before the lecture. There were two very visible *repeaters*, and there might have been many more, which faithfully copied the master compass. One of these repeaters drew a well-damped curve showing how the master compass was gradually getting into its proper north position where it would remain so long as the wheel rotated. One of the repeaters, called the *steering repeater*, had a compass card in which, near the lubber line, the divisions of the card were four times as large as usual; in fact, one degree was really represented by four degrees, giving four times as much accuracy in steering, besides giving less strain on the eyes. Its construction and the construction of the other exhibits were easy to understand by mere inspection. The lecture was illustrated by many lantern slides. As the readers of this abstract cannot see the master compass (Mr. Brown exhibited one detached from its binnacle) here is a brief description. Instead of letting gravity act as with a pendulous weight, Mr. Brown has two bottles connected by a horizontal tube and containing oil. The wheel in its case is really a blower, and air comes under pressure to a valve to establish a pressure difference between the bottles, which is proportional to the tilt, so that the difference of weights of oil in the bottles is proportional to the tilt. The action is just the same as that of a pendulous weight. Another, smaller, pair of bottles is acted upon in just the opposite sense, so as to oppose the first pair, but the tube connecting these smaller bottles is greatly constricted; it results that the oscillations are damped,

[1] Mr. Brown illustrated dynamic balance by suspending a child's hoop by a string and swinging it to the north and south. The hoop sets itself with its plane east and west. Then he fixed a similar hoop at right angles to the first and swung the combination to show that it did not tend to set itself in any direction. It is now in dynamic balance.

and the curve drawn during the lecture by one of the repeaters showed how very effective the damping is.

The gyro case and bottle system is supported on knife edges (on the level of the centre of gravity) on a vertical ring which is supported below on a frictionless mounting (the oil pump), and above carries the compass card. The whole is carried on gymbals and an outer row of springs to take up shock.

A second air jet is employed to work the repeaters. It acts upon a pair of contact-making vanes, and these contacts, through the agency of 'the controller,' which is fixed on the switchboard, work the repeaters and a step-by-step motor which forces round a follow-up ring to keep the contact-making vanes always opposite the air jet. When the compass is fixed to a rolling table which imitates the rolling of a ship it is interesting to see that the motion of the oil in the larger bottles is a quarter period behind the roll, whereas the pendulous motion synchronises with the roll. This is the reason why there is no quadrantal error.

The idea of a gyro-compass is old, but Anschütz deserves great credit for first carrying out the idea. He knew that the directive action of the earth was exceedingly feeble, and he had amazing courage in placing the instrument on a rolling, pitching, plunging ship. One of the Brown compasses on a flagship in stormy weather in the North Sea about a year ago was subjected to particularly accurate observation, and it was found never to depart more than one degree from the true direction.

The reader of this abstract is under the disadvantage that he cannot see the experiments or lantern slides, or the whole compass or its parts, and at two places short explanations by the abstractor have been given instead of the longer popular illustrated explanations of the lecturer.

Corresponding Societies Committee.—Report of the Committee, consisting of Mr. W. WHITAKER, F.R.S. (*Chairman*), Mr. WILFRED MARK WEBB (*Secretary*), *the* Rev. J. O. BEVAN, Sir EDWARD BRABROOK, Sir H. G. FORDHAM, Mr. A. L. LEWIS, *the* Rev. T. R. R. STEBBING, Mr. MARK L. SYKES, *and the* PRESIDENT *and* GENERAL OFFICERS *of the Association.* (*Drawn up by the Secretary.*)

THE Committee reports that the following are the officers of the Conference of Delegates, to be held at Bournemouth: *President*, LORD MONTAGU OF BEAULIEU; *Vice-President*, Mr. WILLIAM DALE, F.S.A.; and *Secretary*, Mr. WILFRED MARK WEBB, F.L.S.; and that the following programme has been arranged:—

'Atmospheric Pollution of Towns,' suggested by the Rochdale Literary and Scientific Society, and introduced by Dr. J. S. OWENS, M.D., A.M.I.C.E.

'The Measurement of Rain,' suggested by the Hertfordshire Natural History Society, and introduced by Mr. CARLE SALTER.

'The Importance of including Geography in the Curriculum for Higher Education,' suggested by the Manchester Geographical Society, and introduced by Mr. T. W. F. PARKINSON, M.Sc., F.G.S.

The Geologists' Association has been admitted as an Affiliated Society, and the Blackburn Naturalists' Society as an Associated Society.

The Committee asks to be reappointed with a grant of 50*l*.

Report of the Conference of Delegates of Corresponding Societies, held at Bournemouth on Thursday, September 11, *and Friday, September* 12, 1919.

President: LORD MONTAGU OF BEAULIEU.
Vice-President: WILLIAM DALE, F.S.A.
Secretary: WILFRED MARK WEBB, F.L.S.

The President welcomed the delegates to Bournemouth, and called upon Mr. Whitaker to propose a vote of condolence to Mrs. Hopkinson on the death of Mr. John Hopkinson which reads as follows:—

The Conference of Delegates of Corresponding Societies desires to express its condolence with Mrs. Hopkinson and her daughters on the death of Mr. John Hopkinson.

He was the founder of this Conference, and its first Chairman, in 1880, ever since which time he has aided greatly in its progress and organisation, and he was President in 1917.

This was seconded by the Rev. J. O. Bevan and carried.

The Secretary reported that the Kent's Cavern Committee had met, that Sir W. Boyd Dawkins had been added to this number, that over £100 had been received as donations, and that steps were being taken to ascertain what was feasible in the matter.

The President then read his Address as follows :—

Roads Ancient and Modern. By Brigadier-General Lord Montagu, *A.I.C.E., A.M.I.C.E. (Member of the Road Board, Adviser on Mechanical Transport Services in India).*

I make no excuse for selecting roads as the subject of my address to you to-day. Roads are now, as ever, a good general test of the degree of civilisation to which a nation has attained, and at the moment in the United Kingdom compared with railways they are of equal, if not of greater, importance to the country.

I do not propose in this address to deal at any length with the comparative merits of roads and railways, or with recent controversies in regard to the new Ministry of Transport, more than to say that amongst the majority of road lovers and road users, the placing of roads under the domination of a Ministry composed almost entirely of railway officials is a retrograde step. In reference to this point it should be remembered that railways have only existed for the short period of about eighty to ninety years. Now, with much altered conditions, especially with the recent increase in the cost of labour employed by railways, and therefore the cost of handling of goods, it is doubtful whether railways can without artificial help given in the form of subsidies or otherwise, hope to retain a considerable proportion of the traffic which they have been accustomed to carry. For many purposes road transport in this small island of ours will be in the future the cheapest and most convenient method of carrying passengers and goods. We are, however, in a transition stage, and nothing but practical everyday experience and economic facts can decide how much traffic is to be road borne or railway borne. It is to be hoped that the new Ministry will show signs of rising above the pro-railway bias with which it is credited, and realise not only the nature of roads and road transport, but the political and social importance of roads as compared with other means of transport.

The history of road development is long and interesting. In the earliest historical times, the means of communication were probably mere foot tracks across deserts, through jungles, and over mountains. In many cases the tracks of large wild animals, such as elephants, buffalo, and deer, formed the only path along which the human being could go, and proof of this is to be seen to-day in certain countries where thick jungle still exists, and where these animal-made paths form regular paths for human beings as well. This may be considered to be the earliest and first stage in the history and development of roads and locomotion upon them.

The second stage may be said to have begun when pack animals began to be used, and horses, donkeys, mules and oxen were driven along the footpaths by primeval man, who had tamed these animals and made them useful in the conveyance of himself and his goods. These early pack roads were often made over swampy places by means of logs or brush wood, and primitive bridges over streams consisted of the trunks of fallen trees. Then there were roads over rocky passes, like the Buddhist paths in Northern India, which were made by heating the rock underneath by wood fires and then pouring water upon it so that it split and disintegrated. Some of these early paths hewn out of the rock—the Malakand path, for instance—can be seen to-day, well engineered with a more or less even gradient, leading from one valley over the watershed to another, or up to the remote forests of the higher Himalayas.

After this period we come to the third stage in roads, when it occurred to man to place upon the path or track stones or gravel, or earth, taken from near

by to fill up the holes in the road and to make a firmer footing for man or beast passing over.

The fourth stage may be said to have begun with the coming of the wheel. What suggested the use of the wheel first can only be conjectured, but the rolling of a log down a hillside, the ease with which a circular stone will jump over obstacles may have been the germ of the idea, and when the wheel came every road used by wheeled traffic began to assume a far greater importance. Probably the earliest record of wheeled traffic is to be found in the Bible in the constant references to chariots throughout the Old Testament, about 4000 years ago. There is probably no record of wheeled vehicles older than this, for the most ancient nations with which we are acquainted, the Assyrians and the Egyptians, both used pack animals, horses, donkeys or camels, for crossing the deserts which surrounded their countries. There was also much use of water carriage on their rivers, such as the Nile, and the Euphrates and the Tigris which ran through the middle of Egyptian and Assyrian territory.

We may consider that the fourth stage in road development began in Roman times, when towards the end of that Empire an effort was made to make a road of solid blocks of stone, such as we see in the still existing remains at Pompeii to-day. The original track of some of these roads still exists to-day all over Europe, as well as in this country. In those Roman days, roads were largely influenced, as indeed they have been in recent times in the case of many continental powers, by military considerations. For instance, roads were made in Roman times not along valleys, but along the ridges of hills, in order that the troops using them might always have the advantage of being on the higher ground. There was also probably an engineering reason for taking the roads along the uplands, in that the higher ground was the better drained, the less liable to flood, and provided a firmer road bed. Instances of this characteristic of Roman roads are to be seen in Watling Street, which leads from the direction of Edinburgh to the direction of Durham. This old road went over the summits of most of the hills in between, such as the Cheviots. Again, the old Roman way between Winchester and Silchester crossed some of the highest points of the Hampshire Downs in a direct line. There are other roads on the Continent made in a direct line, ignoring the desirability of better gradients, and refraining from using valleys as the naturally graded means of access between watershed and watershed. These Roman roads and their consequential effects formed one of the most important direct results of Roman civilisation. This influence lasted right through the earlier periods of European history. Through the Middle Ages no particular attention was paid to roads for vehicles except when military requirements were urgent. The use of pack horses was the rule; roads the exception.

The fifth stage came when our ancestors floundered over roads which were in winter often nothing better than semi-morasses. Thus they remained until the coaching era began, some 150 years ago, when the necessity for conveying mails and passengers at what were considered then high speeds—an average of eight to ten miles an hour—brought about revolution in road construction.

The sixth stage began with the work of Telford and Macadam in the middle of the nineteenth century and their influence exists till to-day. It is a curious and interesting fact that just when roads in 1830-40 were beginning to be put into order and road traffic was coming into its own, and the earliest motor-cars were being tried, the railway era should at that moment have commenced. One cannot fail also to see the modern parallel, when roads and transport upon them are once more just reaching a very high state of development that a Ministry composed almost entirely of railway officials should have been allowed by Parliament to control the future destinies of the road.

Macadam's principle, which has stood the test of time, was that no broken stone larger than could be passed through a 2½-in. ring should be used in road making. He also urged that there should be adequate foundation on which the broken stone should be placed, that the whole should be consolidated by rolling, and the road should be planned with a camber sufficient to drain its surface. All these points were thought out and insisted upon by Macadam, who may be justly called the pioneer and father of modern road engineering. It is also interesting to note that it has lately been recognised that the permanent

way of railways should be constructed on much the same principle, namely, made of broken stone on which the sleepers are laid. Railway companies, in this respect many years behind the proved practice of road experts, are now beginning to realise that a permanent way so made provides a better road bed, costing less to keep in order, and one that diminishes the strain and wear upon locomotives and rolling stock. In other works, the principles of Macadam are being tardily applied to the road bed of the principal railways nearly 100 years after Macadam's era, and the old-fashioned system of ballasting with anything handy, such as water gravel, sand, or even clay or common earth, is being abandoned.

The seventh stage of road development may be said to have commenced with the advent of the motor-car in 1897, some twenty-two years ago. As one of the pioneers of those days, I can remember when many of our main roads twenty years ago were partly covered with grass which had invaded the metalling and was growing year by year towards, and even in, the centre of the road. In those days the through traffic to be met in a day's journey along many miles of main road through the Midlands and the South of England and Scotland and Wales was almost nil. Roads and road transport by horse vehicle had been killed by railway competition and by neglect. Wherever railways were available for use, horse-drawn traffic had ceased to exist, at any rate for distances exceeding fifteen miles. It was too slow and inconvenient to be much used for long distances, and therefore mechanical vehicles in the early years of this century found many important roads deserted and neglected. About the year 1900 the more progressive and far-seeing among road surveyors began to realise that the coming of the mechanical vehicle must mean the revival of public interest in roads, the increased use of roads, and the necessity for further investigation as to how it might be possible to make roads more durable. Bituminous roads, waterproofed yet somewhat elastic in their surface, were tried, and after initial experiments this system began to prove itself. Gradually all over the United Kingdom, to say nothing of the more progressive nations of the Continent, the use of tar and bituminous substances greatly increased. To-day, the main roads of this country are for the greater part of them composed or surfaced with either a bituminous material or are tarred at regular intervals to preserve the crust, and keep down dust and reduce expenditure on maintenance. A good bituminous road, once made, is undeniably cheaper than the old-water-bound road to maintain. In towns the diminution of scavenging required, and the non-filling up of drains with the detritus of the road, have also saved much extra expense in the maintenance of a bituminous over an ordinary water-bound surface. Upon main roads in country districts where the wear on the road is much less than in a town, the durability of the bituminous surface, though it has not yet been scientifically ascertained, is undoubtedly greater than was for a long time supposed. Once more in this instance economy and efficiency have gone hand in hand.

The modern idea of direct through road communication, that is, roads between important points far apart, such as London and Edinburgh, London and Holyhead, London and Bristol, was originated in this country by Telford, who was at one time employed by the Government Commissioners charged with making Highland roads. Telford and his pupils rightly planned main roads to avoid minor towns and villages, and, after the manner of the great Napoleonic roads in France, main roads went as straight as possible between towns of importance. The Great North Road is an example of this between London and the northern end of Leeming Lane on the borders of County Durham. Ample width was another feature of these main roads, the waste of the highway, as it was called—that is, the portion of the highway outside the metalled portion of it—being used in those days by horsemen, and nowadays for the deposit of road metal for repair purposes. In some cases this waste was used for the purpose of extracting from beneath suitable metal for repair, thus cheapening the cost of maintenance of the road at a time when carts, horses and men were no doubt keenly occupied in agriculture and difficult to obtain for road-making purposes.

It is a scandalous but undeniable fact that since the days of Telford and Macadam no new main roads have been made in this country, neither has any considerable mileage of secondary road been constructed. And it is not as if

during the last twenty years development of the country by-roads had not been needed socially and commercially. The old crooked lanes of our forefathers, which had perforce become the main roads in many cases, full of dangerous corners, were seldom direct routes between important points. But some of these have endured till to-day. All over the country, it can be said with truth, hundreds of miles of unnecessary road mileage are to-day in use owing to the fact that new main roads have not been constructed, suitable for traffic and leading direct from place to place.

I may mention here that the Road Board, whose ten years of good and useful work has just come to an end in consequence of the formation of the Transport Ministry, had several schemes for the construction of new main roads in hand, especially in and near London. The revenues of the Road Board, which this year would probably have amounted to over three and a-half millions sterling, derived from taxes on carriages and on motor spirit, would also have helped much in new road construction. These revenues have now been taken away from the Road Board and absorbed into the Exchequer. The war has justified many things, but the breaking of the Parliamentary bargain made in 1908, by which the taxes on mechanical and other vehicles and on motor spirit were to be used for road purposes, is entirely unjustifiable. This three to four millions a year was improving the roads at no cost to the ratepayer or the State, and it was but mere justice that those who were using the roads were helping to pay for them. This sound practice should be revived at the earliest possible moment, but as Parliament has recently allowed the subordination of roads to railway interests in the recent Transport Bill, it can only be by the steady work of those who believe in the future of roads that Parliament can be brought to see once more the importance of road questions.

As to the future of roads in this country, had it not been for this recent regrettable step on the part of the Government, it would have been possible to speak in hopeful terms. The daily increasing importance of the scientific investigation of problems of road transport and of road construction is obvious. But it is to be feared now that politics will begin to affect road questions. Hitherto the Road Board has not been influenced in giving grants by any political consideration. But in future, here as in some other countries, road grants will undoubtedly be used as bribes by unscrupulous candidates and members of Parliament. Soon we may live to read : 'Vote for So-and-so, who has promised to secure larger grants for local roads!' Members of Parliament will very soon find out that the votes of ratepayers can be influenced by the making or non-making of new roads out of public moneys, by the amount of grants given for the maintenance or improvement of existing roads, and the building of wider and stronger bridges. They will be tempted to use their opportunities of political pressure in Parliament to gain votes at the expense of road efficiency or proper road policy. In the early railway days members of Parliament often tried to please their constituencies by supporting or opposing construction of railways. It is to be feared that roads will be used in the future in the game of party politics. 'Graft' instead of merit will, I fear, often decide future questions concerning roads and road transport, just as railway policy in some countries is one of the chief planks in the programmes of political parties.

There is another aspect of roads which is more attractive than that just discussed. 'How is the road of the future likely to be made?' Quite recently several new forms of artificial or treated road-stone have been the subject of experiments. Some of these are merely improved forms of slag or hard stone, heated and then immersed in a bituminous substance; others are made artificially, like wood blocks, stone setts, etc., and are intended to be dressed and laid down in varying fashions. Some of these consist of rough glass blocks, which promise to provide a durable kind of surface, far less slippery than wood blocks or asphalte, and wear-resisting in a high degree. With a road made of this kind of material the camber need be very slight, a point of great advantage to all traffic, especially horse-drawn. Some of these new road materials also provide an outlet for the use of by-products now wasted. Kleimflaster, as used on the Continent and now to be seen on the Chelsea Embankment, is worthy of a more extended trial. Then there is the road made of small stone setts carefully laid on sand or other foundation, as in France, now to be seen on the new direct

road between Paris and St. Germains. There are also new possibilities in metal plateways, with lengths of steel plate laid down, one set for the up and the other for the down traffic, on main roads, over which various types of mechanical vehicles would run. All these are efforts to get away from road surfaces which present great resistance to the passage over them of wheels. The barbaric system of spreading loose stones and leaving them to be crushed in by the traffic itself is, I hope, dying out even in remote country districts. Then, also, the dirt and wastefulness of roads made with water-bound material is being realised. Broken stone or gravel consolidated by water and traffic only leads to speedy deterioration by weather and wear, and, in addition, there is the inevitable constant scavenging to remove dust and mud inseparable from non-waterproofed roads.

Nearly everyone talks of the wear of the road without realising what the expression means. The wear of the road is not caused, as many people think, by the wheels merely rolling over the surface of it, though on weak roads heavy loads on too narrow tyres crush the materials of which the surface is composed. The main cause of the wear of the road comes from what is called the 'inter-attrition' of the stones beneath the surface. When the surface yields to the horse's hoof or to the weight caused by the loaded wheel, something has to move beneath, and the stones which lie between the surface and the foundation are thus rubbed one against the other. The result is that their edges are ground away, a process which produces dust and mud, which in their turn come up through the interstices of the stones to the surface. It is an interesting fact that stones taken out from below the surface of the road often show signs of wear greater than those actually on the surface, owing to this grinding action.

As regards the evolution of the road vehicle of the future, in a few years' time, except for agricultural purposes, the horse-drawn vehicle as a means of conveyance of goods will, in my opinion, be extinct. The horse will, nevertheless, always exist for riding purposes, and to a certain extent for agriculture, but as an animal he is unfitted by nature for draught purposes, and his range and mileage is very limited compared with the mechanically propelled vehicle. More and more, too, will the use of mechanical transport on roads be regarded with favour, owing to the immense advantage of the conveyance of passengers and goods from place of origin to destination effected by this and by no other means. The railway station is rarely the place of origin or the destination of either passengers or goods. You have to move yourself or your goods to a station by means of the road or road transport, and from the station by like means. There are thus at least ten to twelve stages in the progress of a parcel from a shop in London to a house in the country. Constant transference by human hands means much cost, especially with the high price of all labour of to-day. Moreover, while railway transport is essentially suitable for goods in large quantities or for very heavy or very fast traffic, it is eminently unsuitable for cross-country journeys or for short distances and for conveyance from manufactory to the ship, or from producer to consumer. In this country, too, where distances are comparatively small to the ports from inland producing centres, there is hardly any great manufacturing district which is beyond the reach of a single day's run with a mechanical road vehicle. From Birmingham to Tilbury, 125 miles, probably is the longest distance from an important commercial to an important shipping point. The great manufacturing centres of Lancashire and Yorkshire are close to their ports of Hull on the one side and Liverpool on the other, for England is here not more than seventy miles broad. The initial advantage of railway transport, namely, the ease of hauling, requiring, say, the small tractive force of 12 to 15 lb. per ton, with a clean steel wheel on a clean steel rail is in itself largely neutralised by the immensely increasing cost of the labour required to operate the railway and handle the goods. On the other hand, on a well-made road the tractive force may be taken at about 45 lb. tractive force per ton, three times as much as that of a steel wheel on a steel rail. But in these days the cost of this extra power produced by steam or gas or motor spirit is insignificant in comparison to the cost of increased labour. The initial advantage therefore of transport on rails is now largely neutralised. It is not too much to say also that railway transport must become year by year dearer, unless radical changes in the methods of operation are introduced, such as the adoption

of Mr. Gattie's scheme, or some genius arises in the railway world who will reorganise and think out afresh on an enirely new basis, methods of railway operation. There is no sign whatever of such a genius at the moment, and Government control or other form of nationalisation will as in other cases tend to stifle progress and discourage valuable inventions.

The coming of the new road transport era will, I fear, be hampered by the threatened establishment of a Government monopoly of transport. But even governments and ministries, however bureaucratic, must bow in the course of time to facts. As a general rule, it may be said that railways tend to concentrate population, while the growth of road transport tends to diffuse population. Railways naturally dislike being bothered with small country stations, and the expense of providing small centres of production with expensive stations, staffs, sidings, etc., is often not justified from a purely financial point of view. Road transport, on the other hand, being available wherever there are roads, good, indifferent, or even bad, can go anywhere. In Normandy and Brittany before the war, from farm lane to farm lane, from small holding to small holding, and from village to village, mechanical road transport picked up produce and left goods in return, with an ease and cheapness impossible to railways. Light railways are from their fixed nature and high cost of operation inferior to mechanical road transport for country districts. Road transport alone possesses the advantage of carriage from door to door without intermediate handling, no time-table is necessary, no expensive junctions, no signalling, no platforms, no expensive bureaucratic staffs, and the amount of capital required to start a local road transport company is represented by a few hundred pounds compared with hundreds of thousands required for railway—even light railway—development. The number of tons per hour which can be conveyed over a good main road compared with the tonnage over even a double line of railway is greater, and from point of origin to destination and faster. In short, railways will have to meet the competition of road transport more and more, and it is interesting to note that Mr. Robert Williams, Secretary of the National Union of Railwaymen and National Transport Federation, in an article in a recent book called 'The Limits of State Industrial Control,' foresees and appears to regret that road transport competition will be severe in regard to railways, and therefore disadvantageous to his union. 'If the railways are nationalised,' he says, 'the State will be faced with the competition of road transport,' and he deprecates the possibility of this occurring. In other words, natural and scientific evolution in regard to transport is to be barred, in order that railways may be run for the benefit of certain unions or of a theory of State control. The interests of the producer and consumer are to be ignored, that abstract entity, the State, is to operate if necessary at a loss, and the development of competition is to be limited, if necessary, by law. Further discussion of this aspect of the question would be out of place on a scientific occasion such as this.

I cannot conclude my address without some reference to the romantic, poetical and artistic aspects of the road. In the Old Testament the road is always the symbol of something beautiful and useful. Throughout the Old and New Testaments the most famous and moving incidents have all taken place in or near the road—roads which we picture to ourselves from youth up. It is along the road that we go to be christened, married and buried. Roads winding over hills and through dales are not only means of travelling but emblems of one of the conquests by man over natural forces, and roads over the face of the world show forth all the extraordinary intelligence and industry of the human race. It was Ruskin who held that the making of a road was the finest work and monument which a man could leave behind him. If we may parallel the well-known saying that 'the man is worthy of his country who makes two blades of grass grow where one grew before,' one might say to-day that he who makes roads twice as good as they have been, who makes them fit for the transport of his country, is as great a benefactor as he who produces more out of the soil. There is something wonderful but indefinable in the charm of a great road which can never be understood by those who have not felt it. It suggests adventure; it stimulates imagination; it brings at eventide the idea of homecoming, of repose after work. Coeval with the earliest civilisation and coeternal with mankind, roads in the future will be valued more and more by the community. Roads will

in the future as in the past form a just criterion of the intelligence and civilisation of every country.

It is hoped therefore that every citizen will prize the freedom of the road, will be zealous in insisting on a higher standard of construction and maintenance, and resist any attempts by whomsoever made to subordinate to political or rival interests the future development and use of our highways.

Sir EDWARD BRABROOK, C.B. (Balham Antiquarian and Natural History Society), proposed a vote of thanks to the President for his eloquent and interesting address. He also congratulated Lord Montagu on his share in a patriotic movement that had done much to restore to public enjoyment the beauties of the roads of the country, and of the scenery which they opened up.

Mr. WILLIAM WHITAKER, F.R.S. (Croydon Natural History and Scientific Society and Essex Field Club), seconded the motion.

The Rev. J. O. BEVAN (Woolhope Naturalists' Field Club) suggested that an expression of sympathy should be given to the President in regard to the anxiety he must feel at the serious illness of Lady Montagu.

The motion was carried unanimously.

Mr. H. M. PLATNAUER (Museums' Association) pointed out that at present there was too much very heavy traffic on our roads, mostly hauled by traction engines, which was spoiling the roads and seriously shaking small houses. All such traffic, he said, should be put upon rails.

Dr. F. A. BATHER, F.R.S. (Wimbledon Natural History Society) asked the President to express his opinion as to the value of tramways as road-users in comparison with other forms of road transport.

Mr. THOMAS SHEPPARD (Yorkshire Naturalists' Union and Hull Geological Society) proposed that the following resolution from the Conference should be forwarded to the Chancellor of the Exchequer :—

> That the Conference of Delegates of the Corresponding Societies of the British Association asks that the taxes derived from motor spirit and carriages should once more be ear-marked for the improvement of the roads, and urges that in future these taxes be entirely devoted to road improvement.

Mr. JAMES E. LIDDIARD (Bournemouth Naturalists' Science Society) seconded the motion, which was carried.

The PRESIDENT said that omnibuses were cheaper to run than tramways, but that much money was invested in the latter, and that they could not be scrapped, and that all means of transport which would bring workers in and out of towns must be utilised.

Dr. J. OWENS (Honorary Secretary to the Advisory Committee on Atmospheric Pollution) then read a paper on 'Atmospheric Pollution.'

Atmospheric Pollution.

It is hardly necessary to devote much time to bringing out the importance of the subject of Atmospheric Pollution; it may be well, however, to indicate briefly a few of the aspects of the question which make it one we cannot afford to neglect. Perhaps the most important effect which atmospheric pollution produces is on the health of people. We are not designed to breathe impure air; although provision is made in the respiratory apparatus for discharging solid impurities, this is not capable of coping with the large quantities of impurity present in the air of some of our cities.

It is now well recognised that all transmissible diseases are conveyed by means of solid particles, and, speaking generally, it may, I think, be said that the importance of solid suspended matter in the atmosphere is vastly greater than that of gaseous impurities. Arising out of this, the need for reconsidering the basis upon which the air required for ventilating buildings is fixed should be recognised.

Other important effects to be considered are : The obstruction of light due to suspended impurities, and the effect on buildings and vegetation of the deposit from the air.

In relation to aviation, the question of visibility is of vital importance, as well as the effect in producing fogs, and these aspects of the question call for careful investigation.

In Pamphlet No. 34, published by the Ministry of Reconstruction, on page 13 it is stated that the smoke from a single factory chimney, about 20 miles to the west of London, could be traced and recognised as far as 30 miles to the east of London, *i.e.*, 50 miles from its source. The smoke from this chimney formed one of the most conspicuous landmarks in the South of England for flying machines. This shows the importance of even a single source of impurity.

Again, there is the fuel-economy side of the question. As will be seen later from the composition of the deposit, a large proportion of the impurity of the air is derived from incomplete combustion of fuel and represents waste.

I do not propose to delay further over this aspect of the question, as its importance from different points of view has already been brought out, and is, I think, fairly well recognised. It may be well, however, before proceeding further to get some definition of what we mean by atmospheric pollution.

Normal air may be regarded as consisting of a mixture of various gases in the following proportions :—

Oxygen	20·94
Nitrogen	78·09
Argon	0·94
Carbon Dioxide	0·03
Helium, Krypton, Neon, etc.	traces
	100·00

There also exists a varying proportion of watery vapour, and the term pollution may be regarded as applying to anything that disturbs the above-described constitution of the air. But in the present connection pollution is interpreted as relating only to such matter, solid, liquid or gaseous, as is not included in the above list of components.

There are certain elements of pollution deposited from the air which may be regarded as entirely foreign to the atmosphere. These are tarry matter, carbonaceous matter derived from smoke, and sulphates. Other impurities, such as organic matter of vegetable or animal origin, mineral matter derived from dust stirred up by the wind, chlorine from sea-spray, and ammonia from decaying vegetable matter, or possibly other sources, can hardly be regarded as abnormal impurities. At any rate, in the present connection the impurities which we shall devote most attention to are those which are of artificial origin.

By far the largest proportion of such are derived from incomplete combustion of fuel, although there are other sources, such as road dust, fumes from chemical factories, and the like, which contribute their quota.

For the purpose of comparison it will be best to take the air of some country station far removed from sources of pollution as representing what we may regard as practically pure air. Although doubtless there are other places which would fulfil the necessary conditions, the only one at which observations are being taken is Malvern Wells, and it will be seen from the figures in this paper what a difference there is between the purity of the air there and in most of our cities.

Work of the Committee.

It is impossible to devote more time to the general aspects of the question, so I propose to describe in this paper the work of the Advisory Committee on Atmospheric Pollution, and to bring out some of the results obtained during the last five years of its operations.

This Committee was formed in 1912, and has published four Annual Reports, commencing in 1914, the fifth Report being now at the printers. To avoid misunderstanding it must be stated clearly that the function of this Committee has been to investigate and measure only, with a view to providing accurate data on the question of degree of pollution; it has been no part of the Committee's work to consider methods of prevention. The Committee is now working under a grant from the Department of Scientific and Industrial Research, and the method adopted is briefly as follows :—

The work of devising methods of investigation and of co-ordinating inquiry, as well as compiling and reporting upon results, has been the duty of the

Advisory Committee. The actual work of taking observations at the different stations has been done by or under the local sanitary authorities. The Committee have now about twenty-five stations scattered over different parts of the country, from each of which monthly reports are received upon the quantity of impurity deposited in a standard gauge. Blank reports are sent to each station for filling in, and these are returned monthly to the Committee's office for filing.

There have been three main lines of investigation followed :—

(1) The measurement of deposited impurity.
(2) The measurement of suspended impurity.
(3) The measurement of acidity.

Most of the data accumulated by the Committee up to the present have been on deposited impurity. The investigation of suspended impurity and acidity of the air is not in such an advanced state, and the Committee are at present at work upon the problem of the best methods of investigation to adopt.

Deposited Impurity.

The special standard gauge devised by the Committee for the measurement of deposited impurity consists of a circular gauge vessel of cast iron, coated with a vitreous enamel, supported in a suitable stand. This vessel exposes a catchment area of about four square feet, and receives the total deposit from the air, which, together with the rain, is passed into bottles fixed underneath the gauge vessel.

At the end of each month the gauge vessel is washed down with some of the water collected, and the water and deposit collected in the bottles during the month is removed for analysis. The insoluble matter is filtered off or allowed to deposit, and the soluble matter estimated separately. A complete analysis of the deposit is not aimed at, but it is divided into the following constituents :—

Rainfall; insoluble matter, which is sub-divided into tarry matter soluble in CS_2, carbonaceous matter other than tar, and ash; soluble matter, which is sub-divided into loss on ignition, and ash. The sum of the soluble and insoluble being returned as 'total solids.'

Although a complete analysis is not made of the soluble matter, certain of its constituents are further estimated. These are sulphates as SO_3, chlorine as Cl, and ammonia as NH_3.

All the constituents of the deposited matter are returned as shown in the blank report form herewith. The volume of water is given in litres and mm. of depth. Other constituents are shown in grammes, percentage of total solids, and in metric tons per square kilometre, the latter form being chosen in view of the Committee's hope that the investigation will become international.

In the following table the composition of the deposit at four representative stations is given.

This table speaks for itself, and shows the great variation in the quantity and composition of the deposit at different places.

A second table is included which shows for the last five years the total impurity deposited from the air at different stations; the figures give mean monthly deposits in metric tons per square kilometre. This table shows only the total impurity, as this will be sufficient for the present purpose.

The division of the year into summer and winter has been adopted in all the Committee's Reports, as it was felt that this was a somewhat natural division which should be followed.

Referring to Table II, we may compare the deposit at the different stations with each other, and we may examine the figures for any variation from year to year.

Although the War has interfered with the continuity of the observations at many of the stations, and the blanks in Table II. are caused by the suspension of observation at different places, the Committee has been fortunate in being able to carry on work during the whole period at about 25 stations. Observations will be renewed shortly at some at least of the places which suspended work.

No. of Report .....

Meteorological Office, London.

Advisory Committee on Atmospheric Pollution.

Report of Observations for Month ending ..... 19 .....

Centre ..... { Gauge No. ..... / Factor 'F' for gauge .....

Collector .....

Volume of Water collected ..... litres = ... Millimetres of rainfall

Total Solids dissolved ..... grammes } dried @ 100° C.
Total insoluble matter ..... }

Total Solids collected ..... grammes = ... tons per sq. kilometre

	Grammes.	% of Total Solids.	Metric Tons per Square Kilometre.
Composition of Undissolved Matter :—			
Soluble in CS_2 (tarry matter)		= ..... %	
Combustible matter insoluble in CS_2		= ..... %	
Ash		= ..... %	
Total undissolved matter			
Composition of Dissolved Matter :—			
Loss on ignition		= ..... %	
Ash		= ..... %	
Total dissolved matter			
Sulphate as SO_3		= ..... %	
Chlorine as Cl		= ..... %	
Ammonia as NH_3		= ..... %	

Remarks :—

Signed .....

TABLE I.*—*Composition of deposit at four representative stations, given as (a) metric tons per square kilometre, and (b) percentage of total deposit. Both (a) and (b) based on mean monthly deposit for a year.*

Stations	Tarry Matter		Carbonaceous or Sooty Matter		Mineral Matter insoluble in Water		Combustible or Volatile Matter soluble in Water		Mineral Matter soluble in Water		Total Deposit		Sulphates as SO_3		Chlorine as Cl		Ammonia as NH_3	
	Tons per K^2	%	Tons per K^2	%	Tons per K^2	%	Tons per K^2	%	Tons per K^2	%	Tons per K^2	%	Tons per K^2	%	Tons per K^2	%	Tons per K^2	%
Oldham, 1915–16 . .	0·22	0·71	6·40	20·08	16·38	53·2	2·41	7·8	5·4	17·5	30·81	100	2·55	8·3	0·88	2·86	0·18	0·58
Sheffield, 1914–15 (Attercliffe)	0·28	1·31	3·75	17·6	9·27	43·5	1·79	8·4	6·23	29·3	21·31	100	2·83	13·3	1·57	7·35	0·08	0·38
London, 1915–16 (average of eight stations) . .	0·112	0·76	2·3	15·6	5·33	36·2	1·98	13·4	5·03	34·1	14·76	100	2·14	14·5	0·68	4·7	0·103	0·7
Malvern, 1915–16 . .	—	—	0·15	8·25	0·26	14·3	0·49	26·9	0·91	50·0	1·82	100	0·42	23·0	0·195	10·7	0·015	0·82

* From lecture before Royal Met. Soc., March 20, 1918. *Jour. Roy. Met. Soc.*, Vol. xliv., No. 187.

TABLE II.—*Total impurity deposited from the air during the Summer and Winter months at different stations, being mean monthly deposit in metric tons per square kilometre.* (*To convert to English tons per square mile, multiply by* 2·56.)

	Summer Months (April to September)					Winter Months (October to March)				
	1914	1915	1916	1917	1918	1914–15	1915–16	1916–17	1917–18	1918–19
Birmingham, Central	21·51	—	—	—	—	24·67	—	—	—	—
Bolton	20·05	16·22	—	—	—	22·63	17·74	—	—	—
Coatbridge	—	9·39	10·65	15·82	15·58	7·89	10·53	14·54	16·88	18·80
Exeter	7·82	7·63	8·47	—	—	9·94	8·74	—	—	—
Glasgow	—	11·85	19·25	17·70	8·97	21·62	18·08	13·76	14·63	15·67
Greenock	8·93	12·17	12·90	—	—	12·17	13·44	16·84	—	—
Kingston-upon-Hull	12·29	12·56	—	—	—	14·84	14·25	—	—	—
Leith	6·25	9·36	9·56	—	—	9·44	9·93	—	—	—
Leicester	—	12·24	11·63	15·04	19·85	—	17·41	12·95	12·77	—
Liverpool	18·83	19·62	—	—	—	18·60	18·67	—	—	—
London	12·48	13·41	13·74	14·72	11·82	13·90	15·97	14·07	13·36	14·38
Malvern	2·22	1·69	1·87	3·09	—	2·05	1·96	4·02	2·12	4·55
Manchester	18·43	19·26	20·42	15·70	15·60	17·21	22·95	18·87	12·32	13·67
Newcastle	13·64	13·63	20·62	25·71	16·15	17·46	20·03	25·83	15·90	18·58
Oldham	20·57	28·76	—	—	—	34·70	32·87	—	—	—
Paisley	13·01	—	—	—	—	18·35	—	—	—	—
Rochdale	—	—	—	34·62	33·84	—	—	—	35·00	23·16
Sheffield	11·20	12·16	—	—	—	13·77	—	—	—	—
St. Helens	—	—	—	19·83	16·46	—	—	—	20·97	19·08
York	7·83	6·09	8·04	—	—	10·25	9·76	8·97	—	—

NOTE.—For London the average of eight stations is given, except in Summer, 1914, when three only were operating.
For Sheffield the average of four stations is given. For Manchester, station at School of Technology only is given.
For Glasgow, Blythswood Square station only is used.

Referring to Table II, we find the highest mean monthly deposit recorded was 35 tons per square kilometre, or about 90 English tons per square mile at Rochdale during the winter of 1917-18. The summer of the same year gave 34·62 tons per square kilometre at Rochdale.

Oldham during the winter of 1914-15 gave a mean monthly deposit of 34·7 tons per square kilometre.

The lowest deposit recorded was at Malvern and amounted to 1·69 tons per square kilometre during the summer of 1915. The Malvern gauge is situated in the open country at Malvern Wells, and may be taken as indicating what we expect our country air to be like if uncontaminated artificially by the smoke and dust of cities. Doubtless Malvern receives some pollution from the cities surrounding, so that, strictly speaking, the air is not absolutely pure, but for our present purpose we may regard it as representing country air.

During the winter of 1917-18, when Rochdale gave 35 tons per square kilometre, St. Helens gave 21 and Malvern 2·12; thus the Rochdale deposit was over sixteen times that of Malvern Wells, whilst St. Helens deposit was about ten times.

When we examine the table for evidence of improvement or otherwise we get the following results, excluding the stations with only two years' record :—

The Coatbridge figures show clear evidence of increasing impurity, as the rise in the amount of deposit during the five winters recorded is very regular and marked.

Glasgow shows a considerable drop in the amount of deposit in 1918-19 when compared with previous years, and we may say, on the whole there is a tendency there towards improvement.

Greenock, observing for three years only, showed a steady deterioration in its air.

Leith, also for three years, indicated a steady deterioration.

The other stations give no clear indication of improvement or deterioration in the air over them. There are, of course, variations from year to year, but it is impossible to say at this stage if a change in the 1918-19 figures represents the beginning of a steady move in either direction.

It would seem from these figures that the shortage of coal and the rationing order has not produced any very marked effect in purifying the air.

To get an idea of the relation which the different constituents of the deposited impurity bear to each other, curves have been prepared for several years, giving the average deposit of each element of pollution for each month for a group of stations varying in number from year to year. These have been published in the Committee's Reports.[1]

The scales for the different curves are not all the same; but a good idea of the relationship of the different elements can be obtained from these curves. It will be seen that the soluble impurities tend to vary together and have a distinct relation to the amount of rainfall. In these curves the ordinates represent tons per square kilometre except in the case of the rainfall, which is given in decimetres. These are plotted above the months, and so the seasonal variation is brought out also. In all these curves it will be observed that the insoluble ash is the only one showing a tendency towards a summer maximum; for example, in the year ending March 31, 1919, insoluble ash made its highest deposit in May and its lowest in August or September.

In dealing with the impurities deposited from the air we have to remember that this does not tell us the whole story. There are suspended particles of such small dimensions that they practically do not deposit and are carried over very wide areas by the winds before suitable conditions for deposit are attained. The measurement of deposited matter does, however, tell us what amount of impurity is received from the air on buildings, plants, agricultural land, etc. The more finely divided and permanently suspended impurity is, however, of great importance, and the investigation cannot be regarded as complete unless this be also taken into account.

[1] First to Fifth Annual Reports, Advisory Committee on 'Atmospheric Pollution,' obtainable from the Honorary Secretary, 47 Victoria Street, London, S.W. 1.

It is probable that the larger particles of soot and dust are deposited comparatively near their source, and indeed there is some indication of this in the quantity of matter deposited in the central areas of cities as compared with the suburbs.

Relation of Deposit to Rainfall.

There has been a suspicion for some time that a relation would be found between the amount of deposited impurity and the quantity of rain. To elucidate this question the deposit has been divided for several years into soluble and insoluble matter, and these have been plotted for a group of stations against rainfall. Curves for three years bearing on this point were exhibited.[1] It was found that no regular relation could be discovered between the deposit of insoluble matter and rainfall, whereas from the first there was indication of some relationship between soluble deposit and rain.

In the curve for the year ending March 31, 1917, the soluble and insoluble matter are both shown plotted over the rainfall, and it will be seen that there is a tendency for the soluble matter to vary with the rainfall, the insoluble varying independently.

This aspect was further dealt with by reducing the deposit at all stations to a figure showing the quantity per 100 mm. of rain, and it was found that such reduction did not produce any greater uniformity in the figures, but rather the reverse, particularly for the insoluble constituents.

In the curve for the year ending March 31, 1918, three groups of stations are plotted : Group A is for sixteen stations scattered over the country; Group B for three London stations; and C for nine Glasgow stations. In this case the soluble matter only has been plotted, and it will be seen that there is still the same indication of a direct relationship with the rainfall.

The line AB has been drawn through the points on the curve which fairly represent the relationship, and this is given by the equation shown on the curve, *i.e.*, calling soluble deposit in tons per square kilometre S and rainfall in mm. R, the equation is

$$S = 0{\cdot}058\ R + 2{\cdot}5.$$

For the year ending March 31, 1919, a similar curve was plotted, and a somewhat similar relationship appeared. The equation for this year was

$$S = 0{\cdot}069\ R + 2.$$

Again, for a group of four years plotted together an equation

$$S = 0{\cdot}081\ R + 1{\cdot}5$$

was found to hold.

There is a general similarity between all these equations, but they are not identical; all of them indicate, in the absence of rain, that there is a certain amount of soluble deposit, represented by the constant at the end of the equation, and that the total amount is some function of the rainfall *plus* this constant. Of course, the amount brought down must also depend upon the quantity present in the air; hence it is not to be expected that the relationship would be the same for each year, and unless we could be sure that the conditions as to quantity present were constant, we could not hope to establish a definite relationship in this way.

Suspended Impurities.

The measurement of the suspended impurities has been the subject of considerable investigation by the Committee, and many methods have been experimented with in order to obtain some suitable means of estimation Without going through the various steps of the investigation, we shall simply consider the methods as finally evolved up to the present.

It was found that the quantity of suspended matter present in the air was so very small as to preclude the possibility of any method involving weighing. We found that in London on an average day the suspended impurity varied from about 15 to 30 mg. per 1,000 cub. ft. Taking the lower figure—that is, 15 mg. per 1,000 cub. ft. for London—the method used should be applicable also to the country, where the quantity would be not more than about one-third of this. It was concluded, therefore, that an apparatus to give a reasonably accurate result by weighing would have to handle a volume of air of at least

2,000 cub. ft. Hence some other method was sought for, and this took the form of a small filter, consisting of a pair of aspirating bottles, by which two litres of air could be drawn through a disc of white filter paper $\frac{1}{8}$ inch in diameter; a discoloured mark was left upon the disc, the depth of discoloration depending upon the amount of impurity in the air. A standard filter was got out on these lines, with which a record can be taken in about fifteen minutes, and the quantity of impurity estimated by the aid of a scale of shades, which scale has been calibrated by weighing, as described in the Committee's third Report for 1916-17.

As the nature of the impurity in cities is sufficiently alike, it was felt that the records thus obtained would give a reasonably correct idea of the amount of suspended impurity.

The subsequent development of this instrument took the form of an automatic filter on the following lines :—

In this apparatus an aspirating vessel is provided, into which water is admitted through a regulating cock at the bottom. A syphon is fixed inside the vessel, which causes the water-level to oscillate at regular intervals between two fixed levels in the vessel; thus, while the water is rising, air is driven out of the vessel, and while it is falling air is aspirated into the vessel.

On the top of the instrument an entrance for air is provided of a fixed diameter, over which revolves a disc of filter paper. Provision is made by which this disc is held against the entrance during the time the air is being drawn into the vessel. The disc is caused to revolve by a weight and string, but the rate of its revolution is regulated by a stop which follows the hour hand of a small clock placed above the disc. The force for clamping the disc is obtained by a pressure-operated flexible diaphragm acting through a lever. The records are given upon a disc of paper upon which the hours have already been marked similarly to a clock-face, and each record is placed automatically opposite the time at which it is taken. Thus the interval between records is unimportant, although this is easily adjustable.

A sample of the latest form of this instrument was exhibited, and it is hoped that useful information will be obtained by its use. Owing to war conditions, it has not been possible to complete the automatic filter until this month; but it is now ready, and the Committee hopes that it will be put to extensive use.

The calibration of the automatic filter is the same as the single-record instrument, as both operate with a volume of two litres of air and filter this through a $\frac{1}{8}$-inch disc of paper. The scale of shades enables the observer to read directly the quantity of impurity in milligrams per cubic metre, as each unit of shade number represents 0·32 mg. per cubic metre.

Acidity.

A special investigation into the acidity of the air has been undertaken, and is being carried out by the Committee's Research Chemist, Mr. G. M. Watson, B.Sc. The experimental work carried out is fully described in the Committee's fifth Report for the year ending March 31, 1919, which will shortly be published.

The great difficulty again has been the small quantity of acid to be measured, so that the ordinary methods of chemical analysis were not directly applicable. A special instrument was, however, designed in which a solution of methyl orange in distilled water is used as an indicator. A few cubic centimetres of this solution are placed in a specially designed absorption tube and a measured quantity of air bubbled through it. If this solution be absolutely neutral to begin with, which it rarely is, and the air is acid, then the colour change in the methyl orange commences at once, and it passes gradually from yellow to red as the air is bubbled through it. The amount of colour change is estimated by means of a tintometer tube placed beside the absorption tube, both being so designed as to permit one to look through the liquid vertically from the tops of the tubes. It was found that the degree of colour change was proportionate to the amount of acid in the air, and that, using the same solution of methyl orange in the tintometer tube, its colour could be matched to the changing liquid in the absorption tube by varying the thickness of the layer of methyl orange solution in the former, as it was found that as the layer looked through was increased in thickness, so viewed in this way the colour changed from yellow

to red. The instrument is illustrated diagrammtically. It will be seen that the colour change in the observation tube can be measured in units of depth of liquid in the tintometer tube, and it only remains to calibre the latter to provide a measure of the acidity. Methyl orange as an indicator has the advantage that it is not sensitive to CO_2, which is a normal constituent of the air.

I will not delay you further by a technical description of the difficulties encountered in this investigation, as they will be fully described in the Com mittee's Report; but I may say that the measurement of the acidity of the air was taken in hand at the express wish of the Department of Scientific and Industrial Research.

In concluding, there are two special points which I wish to lay special emphasis upon. The first of these is the need for further observing stations, not merely in cities, but in places where there is believed to be little pollution of the air, such as seaside health resorts. It is very important to know what standard of purity we may expect in the air. I feel sure, also, that in some at least of our health resorts, which have developed into large cities, the air would be found to be considerably polluted.

The second point is the need at this stage for extending the work of investigation and measurement so as to include not only the nature and degree of pollution but means for prevention. I suggest that this be dealt with from the present point of view rather than as a side-issue of a fuel-economy research. Incomplete combustion is a chief source of impurity, but there are other sources to be considered, such as road dust, chemical fumes, destructor fumes, and the like, and it has also to be remembered that from a fuel-economy point of view alone it might not pay entirely to do away with smoke.

Mr. T. Sheppard (Hull Scientific and Field Naturalists' Club) referred to the conditions obtaining in Hull.

Sir Napier Shaw (Director of the Meteorological Office) pointed out that Dr. Owens had not represented fully the service which the Advisory Committee for Atmospheric Pollution had rendered to the community, and particularly had omitted to notice the extent of his own share. The standard gauge was criticised by persons accustomed to laboratory work because it only represented the atmospheric pollution collected during the month. But the standard gauge represented the first practical attempt to measure the amount of pollution that falls in an open space, and as a first contribution it is of great value, although, like all other observational work, it does not necessarily answer precisely the question one would like to put. The automatic filter, which was taken in hand spontaneously by the Committee at the same time as the standard gauge, is now completed according to Dr. Owens' original designs, and may be recommended for inspection as a masterpiece of ingenuity. The research in acidity was conducted by Dr. Owens with an assistant, Mr. Watson, who was trained at the Imperial College of Science. The chief part of the work of the Committee is carried out by Dr. Owens with valuable assistance in the technical details of the chemical processes used in analysing the products.

Mr. T. W. Sowerbutts (Manchester Geographical Society) asked whether the increase of pollution during the past four years might not have been due to a considerable extent to the great difficulty during the War which manufacturers and other users of coal have experienced in obtaining the fuel most suitable for their requirements, with the result that much unconsumed smoke has been allowed (partly through the leniency of magistrates) to vitiate the atmosphere.

Professor Lea said that not enough pressure was put on to the users of fuel who would get more power and economy under scientific control, while pollution would be lessened. He gave an instance where the services of a scientific student were put at the disposal of a paper mill, with the result that five thousand pounds worth of coal was saved in one year.

Dr. J. R. Ashworth (Rochdale Literary and Scientific Society) referred to the enormous deposit from the atmosphere which takes place in Rochdale, amounting to nearly one thousand British tons per square mile in the course of a year, and pointed out that it was likely that a good deal of this might be carried into the town from South-East Lancashire by the prevailing west winds, the Pennine Hills to the east of the town, acting as a barrier to passage of

smoke-laden air. The difficulty was to test this view. Recently a wind screen, such as Dr. Owens described, had been put up in Rochdale in the hope that it would give some indications as to the direction from which most of the pollution came. A more satisfactory plan would be to have a chain of gauges in a direction east and west, if authorities could be induced to put them up. More gauges, simple and easily recording, were much needed all over the country if any improvement was to be effected. No one local authority can do much alone, and to have concerted action pressure must be brought to bear from the Government.

He also drew attention to the fact that since coal-rationing came into force there had been a marked reduction in the amount of tar in the atmospheric deposit of Rochdale, which showed that, with a more careful consumption and combustion of coal, a great improvement in the state of the atmosphere might be brought about.

Professor W. W. Haldane Gee said that Bournemouth in September was the wrong place to study air-pollution, which appeared to be a minimum. In large towns such as Manchester air-pollution was a very serious problem. He suggested that the time was opportune for the Advisory Committee on Atmospheric Pollution to turn its attention to a study of the methods for preventing the contamination of the atmosphere. At Manchester, the Advisory Board on Air Pollution of the City Council is directing researches relating to domestic heating, with a view to lessening air-pollution and effecting fuel economy.

With reference to the study of pollution, assistance would be given by the increase of the number of gauges, which might at the same time be employed to measure rainfall.

Mrs. Ellis Chadwick pointed out that air-pollution of the atmosphere is of the utmost importance to women, as they have the task of getting rid of the dirt which finds its way into the house. It also prevents the housekeepers from having open windows, as what should be fresh air is often dirty air. Window curtains and clothing suffer much more in some districts than others, on account of the uncleanliness of the atmosphere, and it is very necessary that we should have clean air to breathe from the question of health.

Dr. Owens replied as follows: Professor Lea raised the question whether polluted air was unhealthy. It has been shown that the incidence of fogs in cities has a great effect on the death-rate from respiratory diseases, and he thought that there need be no question as to the injurious effects of breathing impure air. Both Professor Lea and Professor Gee spoke of the importance of a policy of prevention, and suggested directions in which to look for improvement. He thought, however, that it would be a mistake to suspend the measurement of impurity in the air, as, whatever steps were taken in the way of prevention, we should require some means of ascertaining whether they were successful or not. Dr. Ashworth asked how the straight line drawn through the curve of rainfall and soluble deposit was fixed. It was drawn by eye, as it was recognised that it could only be an approximation; in fact, it must be some form of curve which approaches a limiting value for high rainfalls, and not strictly speaking a straight line. Professor Gee's suggestion of a combined rain and deposit gauge seemed to be a very good one, and should be considered carefully.

At the second meeting of the Conference, held on Friday, September 12, the President again took the chair, and Mr. M. de Carle S. Salter (Superintendent of the British Rainfall Organisation) read the following Paper:—

The Exposure of Rain Gauges. By M. de Carle S. Salter (*Superintendent, British Rainfall Organization*).

The measurement of rain is commonly described as the most simple of all meteorological observations, and from the point of view of the actual operation the statement is no doubt justified. It is fortunate that this is so, for the phenomenon of rain, in regard to its distribution in space and time, is in some respects so capricious and irregular that in order to study it successfully, observations are required from a far greater number of points than suffice

for any other meteorological element. Moreover, the records which are of the greatest scientific value are frequently those made in sparsely inhabited regions; it is therefore often necessary to depend upon the assistance of uneducated, and sometimes illiterate, observers. The process of observing must therefore be reduced to its simplest terms, and instruments must be devised as far as possible 'fool-proof,' and free from all complication.

The evolution of the standard rain gauge as we now know it[2] was a slow and laborious piece of work. The several long series of elaborate experiments conducted at the inspiration, and under the guidance, of the late Mr. G. J. Symons, F.R.S., and described in the earlier volumes of *British Rainfall*, bear eloquent testimony to the care and labour expended on the subject. The reasons for the rejection of non-standard types of rain gauge are cogently set forth by Dr. H. R. Mill in his paper, 'The Best Form of Rain Gauge, with Notes on other forms' (*Q.J.R. Met. Soc.*, vol. xxxiii., 1907, pp. 265-272), and it is not necessary to recapitulate them afresh.

Whilst by no means assuming that the last word has been said on the subject of improving the standard rain gauge, it is a matter of great interest to note that observations made by means of this gauge in nearly every instance satisfy the extremely severe tests imposed by Dr. Mill's cartographic methods of working with rainfall records in a far more satisfactory manner than do those derived from non-standard gauges. These tests have been so extremely numerous and so unmistakably conclusive that the question of the superiority of the standard gauge over other patterns up to the present devised may be regarded as settled.

The adoption of the standard rain gauge marked an important step in the solution of the problem of accurate rainfall recording, and its substitution for obsolete forms has steadily progressed during the last fifty years, but the fact that by far the majority of rainfall observers in this country are voluntary, and equip themselves, makes it impossible to ensure the entire suppression of inferior patterns. Unfortunately, the comparative simplicity of construction of a rain gauge induces certain makers, with no interests beyond the sale of their goods, to continue to put on the market gauges of undesirable patterns, sometimes inaccurately graduated, and these are often purchased in good faith by the uninstructed on the word of a salesman that they are 'of the usual kind.' It is necessary continually to counteract this tendency by the free issue of the pamphlet, 'Rules for Rainfall Observers,' describing the approved gauge, where it can be obtained, and the methods of using it. The issue of certificates of accuracy in respect of non-standard gauges has been discontinued.

The adoption of the standard hour (9 h. G.M.T.) for the observation of rainfall was another of the organizing triumphs of Mr. Symons. The difficulty lay less in the selection of a convenient hour than in the task of bringing about the nearly complete uniformity of practice which was secured, bearing in mind that it was, and still is, impossible to *insist* upon compliance in the vast majority of cases. The unquestioning acceptance of advice on this point has been of immense assistance in simplifying the study of daily rainfall, it being now possible to plot several thousand daily records on a map in complete confidence as to the identity of the period under observation in all but a small number of instances, which as a rule declare themselves at once. During the last few years this uniformity has been to some extent marred by the introduction of 'summer-time.'

The satisfactory outcome of the adoption of uniform instruments, methods, and hours by so large a proportion of the corps of 5,000 observers now at work in the British Isles, removes some of the most serious difficulties which confronted those who first set themselves to study the subject, or rather reduces these difficulties to comparatively manageable proportions. It is still necessary continually to urge more complete uniformity, and every approximation towards this end improves the utility of the observations as a whole.

[2] The standard rain gauge is at present made in three principal patterns—the Meteorological Office pattern, the 'Snowdon,' and the 'Bradford'—differing essentially only in the size of the funnel and in capacity. A common feature is the vertical rim above the funnel.

A more difficult problem, and one up to the present only partially solved, lies in the most suitable method of exposing a rain gauge so that it shall give as true as possible an account of the amount of rain falling. The earlier attempts to solve this problem suffered from an incomplete appreciation of the real nature of the difficulty. Numerous experiments, among the most elaborate of which were those carried out at Rotherham from 1868 to 1890,[3] confirmed the previously observed fact that with practically no exception, rain gauges exposed at a considerable height above the ground caught an amount of rain diminishing with elevation. An extraordinary volume of discussion took place as to the reason of this, and it was many years before it was at all generally recognized that as a matter of fact the variations observed depended not upon the amount of rain falling in the vicinity of the gauge, but solely upon the proportion of that amount which the gauge was capable of intercepting. Much attention was devoted to quantitative observation of the variations, largely wasted labour, for subsequent experience has shown that different conditions of exposure to wind produce entirely different variations, the diminution of catch depending entirely upon wind and little, if at all, upon mere elevation.

The practical outcome was, however, eminently useful, the experiments leading directly to the adoption of one foot above ground as the standard height for the top of the funnel of a rain gauge. This rule, once decided upon, was rapidly brought into general use, and at the present day a very large percentage indeed of the rain gauges in use in the British Isles are placed at one foot above ground. It is to be observed that the British practice in this respect is at variance with the Continental, exposure at 1·5 metre being recommended in most countries of Europe. So far as I am aware, the only valid objection which has been urged to the exposure of gauges at one foot is that in case of deep snow the instrument may be completely buried. Whilst the risk of this occurring on rare occasions is no doubt obviated by elevating the gauge, it appears to have been overlooked that the loss of catch occasioned by elevating a gauge is, as a rule, far greater in snow than in rain, and except possibly in localities where deep snow frequently falls, or in which drifts are of common occurrence, the remedy is worse than the disease.

The advantage of placing gauges with the rim comparatively close to the ground lies entirely in the fact that when a gauge is freely exposed to the sweep of the wind, eddies are apt to be set up round the funnel, which prevent raindrops from entering. Close to the ground wind movement is at a minimum, and the rain falls more nearly vertically than at greater elevations. In a sufficiently sheltered site, such as a walled garden, no diminution of catch will be observed, even if the gauge is raised to several feet above the ground, the requisite wind check being provided. The greater relative loss in elevated gauges during snow is due to the greater facility with which snow-flakes are carried by wind than are rain-drops. In confirmation of the fact that it is over-exposure and not mere elevation which causes the diminution of catch with height, it will be found that a gauge placed on a flat house roof, provided with parapets to break the wind, will indicate as much as one on the ground, whereas if there are no parapets the catch will be reduced by from 20 to 40 per cent. The formation of wind-eddies is very much aggravated if a gauge, in addition to being exposed to wind, is placed on a site sloping downwards in the direction of the prevailing wind. Land sloping to the windward is highly detrimental even if a considerable distance from the gauge whilst the latter stands upon level ground, unless some effective wind-screen intervenes. Thus a gauge should not be placed on a hillock or on a terrace. A sloping house-roof is an extremely bad position.

I have frequently seen rain gauges placed on the ridges of high hills for the purpose of ascertaining the rainfall at the summit. Such gauges, owing to the sweep of wind, almost invariably indicate smaller falls than the valley gauges on both sides, although the actual rainfall at the top is, as a rule, greater. The frequency of snow in these exposed situations adds to the inaccuracy.

The defect in the catch of rain in the case of gauges exposed under conditions such as those described, increases with increase in the average wind

[3] See *British Rainfall*, 1868 to 1890.

velocity, and thus sites which would, *ceteris paribus*, be tolerable in a sheltered valley may be extremely unsuitable near the sea or in a high, windy situation. At inland and not unduly windy stations a gauge may often be placed on level ground with no artificial shelter from wind at all, but with increasing wind velocity increasing shelter, especially on the side of the prevailing wind, is imperative. The diminution in catch observed in gauges placed at more than one foot above the ground becomes increasingly greater as the position is more exposed. Should the gauge used be of non-standard pattern, with shallow funnel, all defects due to wind-eddies are aggravated, and in extreme cases the record becomes quite useless.

Except in very wind-swept localities the loss of catch due to wind-eddies is almost entirely confined to the winter months. In our paper on 'Isomeric Rainfall Maps of the British Isles' (*Q.J.R. Met. Soc.*, vol. xli., 1915, pp. 1-25), Dr. H. R. Mill and I established the fact that on the average of a number of years the percentage of the annual total rainfall occurring in any month does not vary appreciably at adjacent stations, even though these are at greatly different altitudes (*e.g.*, Fort William and Ben Nevis Observatory), depending upon geographical and not upon orographical factors. It follows that the percentage of the summer rainfall to that of the winter in the same neighbourhood, on the average of several years, is a constant. Frequent examinations of the records from unsuitably exposed rain gauges have shown that the percentage of the summer rainfall observed during the winter is always smaller than that found at properly exposed stations. When computing annual average values it is often advisable to ignore the records for the winter months and to substitute for them values computed from the summer rainfall by applying a ratio derived from neighbouring sound records. By this means one is able to arrive at a reasonably accurate annual average for stations with defective exposures. This method has been utilized extensively in constructing annual average rainfall maps, and has been found to yield satisfactory results.

Over-exposure of rain gauges is probably the most fruitful source of error in rainfall observing, and far too little attention has hitherto been paid to it in selecting sites for rainfall stations. It is extremely difficult to lay down any simple instruction which will entirely meet the case. A system of inspection by officials thoroughly conversant with the varying requirements of each locality would do much to remedy the defect, but some time must elapse before any such scheme could be put into effective operation.

The opposite pole of danger in respect of faulty gauge exposure—*viz.*, over-shelter—is much easier to avoid. Whilst it is true that a degree of shelter which would be harmful in one case would be much less so in another, broadly speaking, the conditions are similar everywhere. It is usually safe to suggest that the top of any object, such as a wall or other building, should never subtend an angle greater than 45° with the gauge. In windy positions, when the rain commonly falls at an acute angle, 30° is preferable to 45°. In the case of growing plants, shrubs, or trees, the angle should in no case be greater than 30°, that is to say, the distance of any such object should be at least twice its height. This allows for growth, which is apt to be overlooked as it takes place. It should be noted that whilst the error introduced by undue shelter by a wall or building is always caused by the interception of part of the rain, that caused by trees or shrubs may be either positive or negative, interception occurring under certain conditions, whilst at other times water-drops hanging on leaves may be blown into the gauge, or drip from overhanging branches. I have come across at least one instance in which a gauge was placed by a careless observer actually under trees, with the result that the positive and negative errors practically balanced, and, until the gauge was inspected, no fault in exposure was suspected. I do not recommend this method of obtaining accurate records!

One of the greatest difficulties in securing rainfall records free from the defects which I have described—and this applies with most force to errors due to over-exposure—lies in the fact that in any individual reading the amount of the error is usually smaller than the difference from the reading at a neighbouring station which may arise naturally. A systematic error becomes more apparent when the totals for a considerable period are compared, but, even

then, it is apt to be mistaken for a geographical variation. The only method of which I am aware, which has given completely satisfactory results in detecting faulty records, is the cartographical method elaborated by Dr. Mill and used largely by the British Rainfall Organisation. In the course of ordinary routine, we have constructed maps, mostly based upon several thousand records, for individual days, months, years, and for the average of a long period of years. As I have shown in my paper on 'The Relation of Rainfall to Configuration,'[4] an individual day's rainfall may, or may not, according to its origin, show any conformation to the land configuration; a month's rainfall is nearly always more or less dependent on the configuration (a winter month's rainfall always); whilst the total for a year, or the average for a period of years, is always very intimately related. In drawing rainfall maps it is common to find certain records exhibiting a want of harmony with others in this respect. Sometimes one record will appear out of harmony month after month. The range of variation which can be safely overlooked as fortuitous diminishes with increase of period. Thus in a single month a variation of, say, 25 per cent. might be due to some local thunderstorm, and in a month when thunderstorms are known to have occurred it would not be safe to assume that an even larger variation was due to error. In a map of the rainfall of a year a variation of 10 per cent., not explained by the configuration, should give rise to suspicion, and in the case of a map of average rainfall for thirty or forty years a 5 per cent. variation would almost certainly indicate error. In a very large number of cases records showing want of harmony in this way have been made the subject of special investigation. In practically every case the gauge has been found to be faulty, either in construction or exposure in one of the ways described. It is true that a very small number of cases of persistent variation remain unexplained, and that the subject is far from fully investigated, but from a body of experience gained during about twenty years devoted to the subject, in co-operation with Dr. Mill, I have confidence in putting forward the opinions expressed in this paper.

The PRESIDENT pointed out that in Hampshire there was a marked difference between the rainfall on the sea coast and that a few miles inland, the cool winds blowing from the sea keeping away thunderstorms coming from the north and during the summer months north-west.

The Rev J. O. BEVAN (Woolhope Naturalists' Field Club) said that local Societies should be encouraged to increase the number of rain gauges.

Dr. J. S. OWENS (Honorary Secretary to the Advisory Committee on Air Pollution) said that Mr. Salter referred to the need for increasing the number of observing stations for measuring rainfall. The Advisory Committee on Atmospheric Pollution experienced the same need for a multiplicity of stations for measuring deposit of impurities. It appeared therefore that now would be a suitable moment for considering whether the rain gauges and deposit gauges could be combined in one instrument. This suggestion was made by Professor Gee and is well worth careful examination, especially as now both the rainfall and deposit of impurity measurements came under the control of the Meteorological Office. The deposit gauge now used was really of the nature of a large rain gauge with four square feet catchment area, the large size being necessary if any estimate of the proportion of tar and ammonia present is to be made; useful information could be obtained from a smaller and cheaper gauge which would receive the rainfall and impurities; the latter might then be separated into soluble and insoluble matter instead of making a more elaborate analysis. His object in speaking was to suggest that the possibility of combining the two measurements of rain and impurity should be carefully gone into before new stations were set up.

The PRESIDENT mentioned that in India at a height of seven or eight thousand feet the first rain often brought down a muddy deposit.

Mr. WILSON L. FOX (Royal Polytechnic Society of Cornwall) asked how the measurement of the soluble and insoluble matter could be carried out in practice by amateur rainfall recorders.

Professor W. W. HALDANE GEE said that a serious demand came from hydro-

[4] *Proc. Inst. Water Engineers*, vol. xxiii., 1918, pp. 45-91.

logists to increase the number of rain gauges. At present adequate calculations relating to water power could not be made in this country owing to the lack of rainfall data. Rain gauges could be so designed that they would also be suitable for observations relating to air-pollution.

Mr. DE CARLE SALTER, in reply, cordially endorsed the suggestion of Mr. Bevan that local scientific societies should endeavour to encourage the recording of rainfall. With regard to Dr. Owens' suggestion he would be very glad of the opportunity to co-operate. He was somewhat doubtful, however, whether the conditions of exposure of the ordinary rain gauge and of the atmospheric pollution gauge were identical. If this obstacle could be overcome there appeared to be no difficulty in combining the functions of the two gauges. He thought, however, that it would be found preferable to place the two side by side, especially in view of the cheapness of the standard gauge. Dr. Gee made a very important point in connection with rainfall observing in mountainous areas whence water supplies and water power must be drawn. It was only by the provision of such records that we could hope to study successfully the relation of rainfall to configuration, the most important factor in this connection.

The PRESIDENT at this point went away to take part in a discussion in the Botanical Section, and the Vice-President took the chair.

Mr. T. W. SOWERBUTTS (Secretary of the Manchester Geographical Society) read the following paper by Mr. T. W. F. Parkinson, M.Sc., F.G.S., on

Geography in the Curriculum of Higher Education.

Some years ago geography had no place in the great Public Schools. The textbooks were bad, and consisted of names and statistics which bored the teacher and made the subject hateful to the pupil. Much had to be learnt by heart, or maps had to be drawn for homework because they were easily marked. It would be difficult to say how often the map of Palestine, showing various features, the chief towns, the tribes, etc., or the journeys of St. Paul was produced. These were often set at the week-end so that no sin would be committed by drawing them on the Sunday.

The elementary schools had a hard grind at facts. Names were crammed in, and heights of mountains, depths of seas, lengths of rivers, and sizes of lakes were known. A boy of ten was supposed to know every county in England and its capital. A lot of useless information made the subject despised.

During the last twenty years a great change has taken place in this country, and five years ago we could say that the teaching of geography was better in the elementary schools of England than in any country in Europe. It had become more scientific. The causes were given to explain the facts. Writings of travellers, explorers, and traders were used in many schools. Good maps showing the physical features were used instead of maps crowded with names. Apparatus was obtained or made by the teacher to explain the facts he taught.

Even to-day our elementary schools—urged on by enthusiasts both in the profession and out of it—have a curriculum of geography second to none, and the thanks of teachers to the Board of Education for their admirable scheme of geography for these elementary schools is not grudgingly given.

It is not so, however, in the higher schools. True, the Board demand a certain amount of geography in every secondary school receiving Government grants, but in many cases it is the minimum which the pupils receive. Nor is geography always as well taught in these schools as might be desirable. In our Public Schools the upper forms receive little or no instruction in geography in many cases.

Until a few years ago geography was not compulsory in the training colleges for elementary teachers, in spite of the enthusiasm for the subject in the elementary schools. It was usually coupled with history, and in one paper which the author saw the geography was complete in the following question: 'Draw a map of England and mark the sites of the chief battles in the War of the Roses.' This has now been changed.

In the Universities geography has some place, but there are few professors, the lecturers are usually badly paid, the equipment is faulty, there are not 'honours' courses in all the Universities, and hence geography suffers. How-

ever, the Board of Education has recently advocated what are known as advanced courses in the best secondary schools. English, mathematics, science, classics, modern languages, have a place, but at first geography was excluded, and even now is only regarded as an advanced subject under very special conditions.

These facts are not good for education as a whole, nor for the subject of geography in particular. The President of the Board of Education wrote the President of the Manchester Geographical Society stating that there were not sufficient geography specialists to warrant the Board in advocating advanced courses in geography. Rarely are teachers prepared for a subject which does not exist. Let the Board sanction the advanced courses in geography and there will be an adequate supply of teachers in a short time.

Probably there never was a time in the history of man when geography was so necessary as at present. No country is self-contained. Each is necessary for all and all are necessary for each. This is especially true for the British nation. We have the largest empire the world has ever seen. We boast that the sun never sets on the British Empire, and that it is always summer in one part or other of the British Empire. We control the lives of more people than have ever formed one empire before, and these have different languages, different manners, customs, dress, and show all grades of civilisation and culture. Unless we know more of this empire, and this is geography, we are unworthy of the trust which is imposed upon us.

How can we expect the respect of Canadians, Australians, South Africans, and Hindus when we know so little of them and their countries and make such small efforts to know more?

The time seems ripe for a great step forward in the teaching of geography.

The Great War has brought home to us the size and importance of our Empire, but we are now in danger of falling back into the old groove. Even at the Peace Conference, peoples, towns, and countries were discussed and settled when some of the members had never heard of either the places or the people. Boundaries have been drawn without any regard to the geographical conditions.

Geographical conditions alone made India a garden protected by the mountains and the sea for a time, but when men had learnt to navigate the seas and to negotiate the mountain passes, India lost her natural protection and fell a prey to invading hordes who envied the natives their rich land. Mesopotamia, owing its greatness to its position near great rivers, rose and declined, but will rise again by a study of its climate and by the application of science to its agriculture. Egypt—that fertile strip in the desert—became a great land through geographical conditions. Greece, Rome, and Spain all rose because favourable conditions prevailed, but failure to keep pace with the times led to their decline.

Is it not also possible that our own Empire may fail when it has the power to be the greatest factor in the world's progress? Every statesman should know his geography well. Every official in our Government Departments should have had a thorough training in the school of geography. It may be truthfully said that not 1 per cent. of the officials in the Higher Civil Service have ever studied geography seriously since their school days. Not long ago the subject was not even among those for examination. Map-making has been left to the Army and Navy Ordnance Survey Departments. The Board of Trade officials should be expert geographers. There should, without doubt, be a geographer at the Ministry of Transport.

Our trade is carried on with every country in the world. We have been nicknamed 'a nation of shopkeepers,' and it is a marvel to any thinking man how we have acquired our markets, and especially how me manage to keep them.

Surely there is a great field for geography teaching in the upper part of the secondary school and in the University, and the tendency to make the subject a branch of history or of commerce is not altogether advisable. It is necessary for commerce, but is not really a part of it. Geography may be called a synoptic science, since it obtains much of its data from other sciences, and it is as old as man himself. The relationship between man and his environment made the study of geography a necessity. Man was, in fact, 'controlled' by geography, and only by a study of the subject can man suit himself to this

control. Land forms and climatic conditions, and the vegetation resulting from these, have accounted for all the differences of the races, for the rise of industry and the developments of commerce. It is only in proportion to our power to overcome the disabilities of our environment that we rise above the level of the savage.

Surely it is necessary to study geography if a right conception of our obligations is to be obtained. Practically all historical teaching should have a geographical basis, and if commerce is to be carried on in a less spasmodic fashion than in the past, a knowledge of geography must be acquired by all our great commercial leaders.

It appears necessary that an honours course in Geography be established in all our Universities, with professors and lecturers like the other leading subjects of a University course. Until this is done the secondary schools will never supply the students in geography except as teachers in elementary schools, or where the subject is compulsory, as in most of our schools of commerce.

One of His Majesty's inspectors once said that any boy could acquire all the geographical knowledge he required. Could not this be said of any subject with equal truth? His point was that there was no call for the subject, since there were no scholarships at the Universities, and no schools there to which a student with geographical inclinations could attach himself. The schools could gain no 'éclat' by passing boys through a geographical course. As he said, 'the subject leads nowhere.'

At the present moment geography needs a man of strong ideas—an enthusiast who could make *his* ideas acceptable to others. Whether this man be an official of the Board of Education, a leader in our Universities, or a common teacher, he has a task which would well repay his efforts. He has a subject which is bound to be of importance in the next few years. Geography will determine the boundaries of States, the Governments of peoples, the development of trade and commerce, and the rise of new industries.

The opening of new trade routes and the improvement of the old also calls for attention from the geographer. Mr. Fairgrieve has said that geographical control is no less potent because it is obscure, hence the necessity of a skilled geographer in almost all our great commercial undertakings.

From the standpoint of examinations some change is desirable. As an examiner in University and scholarship examination, together with many years' teaching experience in secondary schools and training colleges, the author can claim some knowledge of the baneful effect of present-day examinations in geography.

Most secondary schools prepare pupils in the upper forms for the matriculation examinations of some University. Would it not be possible to have a more uniform syllabus for all the Universities. It is practically impossible to prepare a mixed class for the Matriculation, the Preliminary Certificate, and the Oxford Senior in the subject of geography.

But even if there were no examinations and no scholarships and no degrees for the students of geography, the subject has a fascination for most boys and girls in the upper forms of a secondary school. It is not so difficult as the classics or mathematics, and many will take a keen interest in a geography course when there is no examination in view. But it cannot be left for anyone to teach. Geography is a synoptic science. It touches on so many different subjects, and forms a meeting-ground for these. Only the specialist can be allowed to determine the boundaries of the subject of geography. He may not be called upon to verify the laws which he uses to support his facts, but he alone can know how to use these laws for his particular work so as to produce a harmonious relationship between man and his environment.

It is the very fact that geography encroaches upon so many subjects that makes it such a valuable school subject. Our outlook upon the world depends upon our culture, and the mightiness of our Empire must inevitably depend upon our power to recognise that geographical factors have controlled the rise and the fall of great empires even before our day.

Mr. Sowerbutts then added the following remarks on his own account :—

I should like to emphasise what, in my opinion, is required. We want more men (and in this connection, of course, man embraces woman) with the

unbounded enthusiasm and activity in the cause of Geography, as exemplified by the late Professor Herbertson.

If we could capture some wandering Carnegie, and persuade him to endow Chairs of Geography at the various Universities, as required, with an adequate number of scholarships, the problem might be solved; but, in the absence of such a benefactor or benefactors, is it not the duty of the Government to ensure that the teaching of so important a subject is adequately provided for and properly encouraged, so that in our schemes of reconstruction one great drawback to our economical, political, and commercial progress may be remedied? For, depend upon it, a full and scientific knowledge of Geography will be more than ever necessary in the immediate future.

If Professor Fleure had not, unfortunately, had to return home yesterday, he would have been here this afternoon. He has authorised me to suggest on his behalf that the Minister of Education should be pressed to appoint a Departmental Committee on Geography, as he has already done in the case of History and other subjects.

Professor Myres and Mr. Peake also desire me to state that it is only their duties in another part of the building which prevent their being present to support very strongly the views here laid before you.

Mr. C. B. Fawcett (Leeds University, and Secretary of the Geographical Section), in starting the discussion, said that the citizen who knows nothing of the countries of the world cannot give a sensible vote on any question. He pointed out that two-thirds of original exploration is carried out by English-speaking men. When it came to giving details of the countries, half was done by Germans, a quarter by Frenchmen, and much less by Englishmen.

He thought that there was a danger of arousing unnecessary opposition by claiming too much for Geography—*e.g.*, to talk of geographical 'control' as if geographical factors were the sole factors affecting human development. They are vital factors in that development, but Geography is not the whole.

Geography aimed at studying the relations and reactions between human societies and the earth on which they live, and on which they depend for all the material bases of their existence. This study was evidently of such vital importance to all citizens that it should be unnecessary to insist on its recognition in all the educational institutions of this Empire. It had been fully recognised in German Universities and Government Departments since the early years of last century, and the knowledge of Geography, which was widespread there, counted considerably in the unexampled expansion of that empire.

The study of Geography had been emphasised in relation to the British Empire. The fundamental factor in Geography was that the world is the unit for human endeavours and human organisation. Hence every intelligent inhabitant of the world should have some knowledge of it, and those concerned in any wide-ranging organisation should know as much geography as possible.

Colonel A. Burton Brown (Hastings and St. Leonards Natural History Society), in order to show the ignorance of Geography, told a story of a Cabinet Minister who, when Colonel Brown mentioned the Sultan of Sulu, said that he did not know that Colonel Burton Brown had been in Africa, and did not think that the Zulus had a Sultan.

Mr. Chisholm (Vice-President of the Geographical Section) urged the importance of being quite clear as to what Geography is. He mentioned that a year or two previously he had been invited by the Civil Service Commission to attend a meeting of a committee appointed 'to define and delimit the subject of Geography.' As soon as the committee met, the opinion was expressed that it would be better not to define it, and in the end the committee determined, with Mr. Chisholm as sole dissentient, to define the subject simply as 'Geography' as understood at the Universities.

Mr. Sowerbutts briefly replied, and expressed belief that Mr. Parkinson's paper had proved a success.

The following resolution was carried unanimously :—

> 'That the Council of the British Association be requested to suggest that the Board of Education should hold an inquiry on the teaching of Geography similar to those which have been held on other subjects.'

Mr. James E. Liddiard (Bournemouth Natural Science Society) said that

as an old Fellow of the Royal Geographical Society, and a traveller in most parts of the world, he had often been surprised at the amount of ignorance of this great subject so frequently displayed, and had continually urged the importance of more thorough instruction in geography for the widening of the outlook of our people, and for giving to them a fuller knowledge of the world, that they might be better fitted for the use of the great trust of the Empire that had been placed in their hands.

Dr. VAUGHAN CORNISH spoke of the need of geography to members of various professions, and maintained that education should be built up on a study of Nature.

The Rev. J. O. BEVAN (Woolhope Naturalists' Field Club) suggested that three subjects naturally hang together—viz., Geography, History, and Economics. If there were left out another important factor—viz., the anthropological element—he would say that there was a danger in accentuating geography. In fact, attention was being paid by teaching and examining bodies to general teaching of the kind desiderated. The Society of Arts examined candidates for a commercial certificate. The College of Preceptors had started an examination on the same subject, and one of our Universities had arranged for a Degree in Commerce. It was also important to note that the textbooks in geography had improved in late years. Finally, he deplored the fact that the survey of the British Empire was very incomplete as regards boundary, regional, and other like matters which furnished the initial bases of geographical knowledge.

Sir E. BRABROOK (Balham and District Antiquarian and Natural History Society) observed that the study of geography was a necessary foundation for that of anthropology. The circumstance that so eminent a geographer as Mr. Chisholm bore the title of Reader in Geography at the University of Edinburgh, instead of that of Professor of Geography, showed that that great University, like many others, had not formed an adequate conception of the importance of the subject.

Dr. HOYLE (Cardiff Naturalists' Society) expressed the opinion that the question was ultimately one of finance, and the best solution would be the establishment of a few well-paid Chairs of Geography in the Universities.

Mr. EDWARD C. BARTON, coming from Queensland, where the University matriculation examinations have been altered at the instigation of the school authorities, almost to include geography, felt that some definition of geography is much wanted in order to limit the demands of the enthusiastic geographer, and thereby disarm those who would relegate geography to a secondary place in education. It was to be hoped that some authority would give us such a definition, and also define geographical education so that it may tend more towards preparing the mind of the young for assimilating and using geographical data and less towards filling that mind with facts. Especially must the enthusiast refrain from the inclusion of more astronomy, geology, meteorology, history, or other charming cognate branches of science than are absolutely necessary to the understanding of geography in its bold outlines.

The Corresponding Societies of the British Association for 1919–1920.

Affiliated Societies.

Full Title and Date of Foundation	Headquarters or Name and Address of Secretary	No. of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
Andersonian Naturalists' Society, 1885 . .	Royal Technical College, Glasgow. Harry G. Cumming	200	2*s.* 6*d.*	10*s.*	Annals, occasionally.
Ashmolean Natural History Society of Oxfordshire, 1828	Miss A. L. Stone, 2 St. Margaret's Road, Oxford .	232	None	5*s.*	Proceedings and Report, annually.
Belfast Natural History and Philosophical Society, 1821	Museum, College Square. J. M. Finnigan .	200	None	1*l.* 1*s.*	'Irish Naturalist,' monthly; Report, annually:
Belfast Naturalists' Field Club, 1863 . . .	Museum, College Square	330	None	5*s.*	'Irish Naturalist,' monthly; Report, annually.
Berwickshire Naturalists' Club, 1831 . . .	Rev. J. J. M. L. Aiken, B.D., Manse of Ayton, Berwickshire	300	10*s.*	5*s.*	History of the Berwickshire Naturalists'Club, annually.
Birmingham and Midland Institute Scientific Society, 1859	J. C. Watkins, Birmingham and Midland Institute, Paradise Street, Birmingham	108	None	10*s.* 6*d.* and 5*s.*	Records of Meteorological Observations, annually.
Birmingham Natural History and Philosophical Society, 1858	Avebury House, Newhall Street, Birmingham. Grace M. Bauer (*pro tem.*)	207	None	1*l.* 1*s.*	Proceedings, annually.
Bournemouth Natural Science Society, 1903 .	R. A. de Paiva, 13 Carysfort Road, Bournemouth	502	None	10*s.*	Proceedings, annually.
Brighton and Hove Natural History and Philosophical Society, 1854	Henry Cane, 9 Marlborough Place, Brighton .	130	None	10*s.*	Report, annually.
Bristol Naturalists' Society, 1862	Miss Ida M. Roper, F.L.S., 20 Berkeley Square, Bristol	150	5*s.*	10*s.* and 5*s.*	Proceedings, annually.
British Mycological Society, 1896	Carleton Rea, 34 Foregate Street, Worcester .	140	None	10*s.*	Transactions, annually.
Buchan Club, 1887	J. F. Tocher, D.Sc., Crown Mansions, Union Street, Aberdeen	180	5*s.*	5*s.*	Transactions, annually.
Burton-on-Trent Natural History and Archæological Society, 1876	A. Slator, D.Sc., 174 Ashby Road, Burton-on-Trent	120	None	6*s.*	Transactions, occasionally.
Canada, Royal Astronomical Society of, 1884 .	Royal Canadian Institute, Toronto. W. E. W. Jackson, M.A	550	None	2 dollars	Journal, monthly; Handbook, annually.
Caradoc and Severn Valley Field Club, 1893 .	H. E. Forrest, 37 Castle Street, Shrewsbury .	164	5*s.*	5*s.*	Transactions and Record of Bare Facts, annually.
Cardiff Naturalists' Society, 1867	G. D. Shepherd, Gresham Chambers, Kingsway, Cardiff	540	None	12*s.* 6*d.*	Transactions, annually.
Chester Society of Natural Science, Literature, and Art, 1871	Grosvenor Museum, Chester. G. P. Miln . .	1,030	None	5*s.* and 2*s.* 6*d.*	Report and Proceedings, annually.
Cornwall, Royal Geological Society of, 1814 .	The Museum, Public Buildings, Penzance. W. H. Pellew.	80	None	1*l.* 1*s.*	Transactions, annually.
Cornwall, Royal Institution of, 1818 . . .	Henry Jenner, F.S.A., County Museum, Truro .	191	None	1*l.* 1*s.*	Journal, annually.
Cornwall, Royal Polytechnic Society, 1833 . .	E. W. Newton, Pendarves Road, Camborne, Cornwall	300	None	10*s.*	Report, annually.
Cotteswold Naturalists' Field Club, 1846 . .	Roland Austin, Public Library, Gloucester . .	116	1*l.*	15*s.*	Proceedings, annually.
Croydon Natural History and Scientific Society, 1870	Public Hall, Croydon. G. W. Moore . . .	113	None	10*s.*, 5*s.*, and 2*s.* 6*d.*	Proceedings and Transactions, annually.
Dorset Natural History and Antiquarian Field Club, 1875	Rev. Herbert Pentin, M.A., St. Peter's Vicarage, Portland	400	10*s.*	10*s.*	Proceedings, annually.

Affiliated Societies—continued.

Full Title and Date of Foundation	Headquarters or Name and Address of Secretary	No. of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
Dublin Naturalists' Field Club, 1885 . . .	Mrs. Long, 4 Palmerston Villas, Upper Rathmines, Dublin	70	5*s*.	5*s*	'Irish Naturalist,' monthly; Report, annually.
Dumfriesshire and Galloway Natural History and Antiquarian Society, 1862	James Flett, Ewart Public Library, Dumfries .	350	None	5*s*.	Transactions and Proceedings, annually.
Durham, University of, Philosophical Society, 1896	J. A. Smythe and J. W. Bullerwell, Armstrong College, Newcastle-on-Tyne	200	None	10*s*. and 5*s*.	Proceedings, half-yearly.
East Anglia, Prehistoric Society of, 1908 . .	W.G. Clarke, F.G.S., 12 St. Philip's Road, Norwich	280	None	Minimum 5*s*.	Proceedings, annually.
East Kent Scientific and Natural History Society, 1857	A. Lander, J.P., 17 High Street, Canterbury .	60	None	10*s*. and 5*s*.	Transactions, annually.
Eastbourne Natural History, Photographic, and Literary Society, 1867	Miss Jay, Technical Institute, Eastbourne . .	220	2*s*. 6*d*.	5*s*.	Transactions and Journal, quarterly.
Edinburgh Field Naturalists' and Microscopical Society, 1869	Allan A. Pinkerton, 20 George Street, Edinburgh	208	None	5*s*.	Transactions, annually.
Edinburgh Geological Society, 1834 . . .	Synod Hall Buildings, Castle Terrace, Edinburgh. T. C. Day, 36 Hillside Crescent	156	10*s*. 6*d*.	12*s*. 6*d*.	Transactions, annually.
Elgin and Morayshire Literary and Scientific Association, 1836	H. B. Mackintosh, The Museum, Elgin . .	115	None	5*s*.	Transactions, occasionally.
Essex Field Club, 1880	Essex Museum of Natural History, Romford Road, Stratford. Percy Thompson, F.L.S.	300	None	15*s*.	'Essex Naturalist,' half-yearly. Special Memoirs, occasionally.
Glasgow, Geological Society of, 1858 . . .	Peter Macnair, F.R.S.E., and H. R. J. Conacher, 207 Bath Street, Glasgow	197	None	10*s*.	Transactions and Proceedings, annually.
Glasgow, Natural History Society of, 1851 . .	Alex. Ross, 409 Great Western Road, Glasgow .	235	None	7*s*. 6*d*.	'Glasgow Naturalist,' quarterly.
Glasgow, Royal Philosophical Society of, 1802 .	Prof. Peter Bennett, 207 Bath Street, Glasgow .	1,000	1*l*. 1*s*.	1*l*. 1*s*.	Proceedings, annually.
Hampshire Field Club and Archæological Society, 1885	W. Dale, F.S.A., F.G.S., The Lawn, Archer's Road, Southampton	250	5*s*.	10*s*. 6*d*.	Proceedings, annually.
Hampstead Scientific Society, 1899 . . .	C. O. Bartrum, B.Sc., and R. W. Wylie, M.A., 32 Willoughby Road, Hampstead, N.W.	289	None	Minimum 5*s*.	Report and Proceedings, annually.
Hertfordshire Natural History Society and Field Club, 1875	John Hopkinson (Librarian), Weetwood, Watford	170	None	10*s*.	Transactions, one or two parts annually.
Holmesdale Natural History Club, 1857 . .	Mrs. Perrin, Owlpen, Redhill	80	None	10*s*., 5*s*., and 3*s*.	Proceedings, occasionally.
Hull Geological Society, 1889	J. W. Stather, F.G.S., Newland Park, Hull . .	55	None	5*s*.	Transactions, occasionally.
Hull Scientific and Field Naturalists' Club, 1886 .	T. Stainforth, B.A., B.Sc., The Museum, Hull .	140	None	5*s*.	Transactions, annually.
Ipswich and District Field Club, 1903 . . .	Miss M. Fletcher, Sproughton, Ipswich . .	143	None	2*s*. 6*d*.	Journal, occasionally.
Ireland, Statistical and Social Inquiry Society of, 1847	Dr. N. M. Falkiner, Herbert Wood, Sparkhall Brown, B.A., 93 Stephen's Green, Dublin	80	None	1*l*.	Journal, annually.
Leeds Geological Association, 1873 . . .	E. Hawkesworth, Cross Gates, Leeds . . .	106	None	5*s*.	Transactions, occasionally.
Leicester Literary and Philosophical Society, 1835	Corporation Museum. F. B. Lott, 7 Stoneygate Avenue, Leicester	257 Membs. & Associates	None	Members 1*l*. 1*s*.; Associates 10*s*. 6*d*.	Transactions, annually.
Lincolnshire Naturalists' Union, 1893 . .	Arthur Smith, F.L.S., City and County Museum, Lincoln	110	None	5*s*.	Transactions, annually.

Liverpool Biological Society, 1886	W. Rimmer Teare, 12 Bentley Road, Birkenhead	80	None	1*l.* 1*s.*	Proceedings and Transactions, annually.
Liverpool Botanical Society, 1906	E. Horton, Common Hall, Hackens Hey, Liverpool	123	None	5*s.*	'Lancashire and Cheshire Naturalist,' usually monthly.
Liverpool Engineering Society, 1875	T. R. Wilton, M.A., 1 Crosshall Street, Liverpool	570	None	1*l.* 1*s.*, 10*s.* 6*d.*, and 5*s.*	Transactions and Report, annually.
Liverpool Geographical Society, 1891	A. Ellis Cookson, 5 Hargreave's Buildings, Liverpool	560	None	Members 1*l.* 1*s.*; Associates 10*s.*6*d.*	Transactions and Report, annually.
Liverpool Geological Society, 1859	T. A. Jones, 27 Rockfield Road, Anfield, Liverpool	91	None	10*s.* 6*d.*	Proceedings, annually.
London Geologists' Association, 1858	University College, Gower Street, W.C. 1. W. Wright, F.G.S., 24 Balham Park Road, S.W. 12	754	10*s.*	10*s.*	Proceedings five or six times a year.
London: Quekett Microscopical Club, 1865	E. K. Maxwell, B.A., 10 St. Charles Square, North Kensington, W. 10	450	None	10*s.*	Journal, half-yearly.
London: Selborne Society, 1885	83 Avenue Chambers, Bloomsbury Square, W.C. 1. W. M. Webb, F.L.S.	1,000	5*s.*	1*l.* 1*s.* and 5*s.*	'Selborne Magazine,' monthly.
Man, Isle of, Natural History and Antiquarian Society, 1879	William Cubbon, Cairbrie, Albany Road, Douglas, Isle of Man	296	2*s.* 6*d.*	7*s.* 6*d.* and 5*s.*	Proceedings and Transactions, annually.
Manchester Geographical Society, 1884	T. W. Sowerbutts, 16 St. Mary's Parsonage, Manchester	634	None	Members 1*l.* 1*s.*; Associates 10*s.*6*d.*	Journal, quarterly.
Manchester Geological and Mining Society, 1838	5 John Dalton Street, Manchester. Noah T. Williams	402	None	2*l.* 2*s.*, 1*l.* 5*s.*, and 1*l.*	Transactions of Inst. of Mining Engineers, monthly.
Manchester Microscopical Society, 1880	William Dixon, Broadwater, 43 Pine Road, Didsbury, Manchester	197	5*s.*	6*s.*	Transactions and Report, annually.
Manchester Statistical Society, 1833	F. Vernon Hansford, 3 York Street, Manchester	144	10*s.* 6*d.*	10*s.* 6*d.*	Transactions, annually.
Marlborough College Natural History Society, 1864	J. C. Alsop, M.A., Marlborough College	200	1*s.* 6*d.*	3*s.*	Report, annually.
Midland Counties Institution of Engineers, 1871	G. Alfred Lewis, M.A., Midland Road, Derby	330	1*l.* 1*s.*	2*l.* 2*s.* and 1*l.*	Transactions of Institution of Mining Engineers, monthly.
Museum Association, 1889	W. Grant Murray, Art Gallery, Swansea	Members (Insts.) 122	None	1*l.* 1*s.*	Museums Journal, monthly.
		Associates (Persons) 103	None	10*s.* 6*d.*	Museums Directory, occasionally.
Norfolk and Norwich Naturalists' Society, 1869	S. H. Long, M.D., 31 Surrey Street, Norwich	283	None	7*s.* 6*d.*	Transactions, annually.
North of England Institute of Mining and Mechanical Engineers, 1852	Neville Hall, Newcastle-upon-Tyne. Allan Cordner	1,194	None	2*l.* 2*s.* and 1*l.* 5*s.*	Transactions of Inst. of Mining Engineers, monthly.
North Staffordshire Field Club, 1865	H V. Thompson, M.A., Central Technical School, Stoke-on-Trent	615	5*s.*	5*s.*	Transactions and Report, annually.
Northamptonshire Natural History Society and Field Club, 1876	H. N. Dixon, M.A., 17 St. Matthew's Parade, Northampton	210	None	10*s.*	Journal, quarterly.
Northumberland, Durham, and Newcastle-upon-Tyne, Natural History Society of, 1829	Hancock Museum, Newcastle-on-Tyne. C. E. Robson and J. A. Richardson	389	None	21*s.*	Transactions, annually.
Nottingham Naturalists' Society, 1852	Prof. J. W. Carr, M.A., University College, Nottingham	100	2*s.* 6*d.*	5*s.*	Report and Transactions, annually.
Paisley Philosophical Institution, 1808	J. Gardner, 3 County Place, Paisley	528	5*s.*	7*s.* 6*d.*	Report and Meteorological Observations, annually.
Perthshire Society of Natural Science, 1867	Tay Street, Perth. S. T. Ellison	310	None	5*s.* 6*d.*	Transactions and Proceedings, annually.
Rochdale Literary and Scientific Society, 1878	J. Reginald Ashworth, D.Sc., 55 King Street, South, Rochdale	224	None	6*s.*	Transactions, biennially.

Affiliated Societies—continued.

Full Title and Date of Foundation	Headquarters or Name and Address of Secretary	No. of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
Rochester Naturalists' Club, 1878 . . .	Edmund Page, 42 Balmoral Road, Gillingham, Kent	110	None	5*s.*	'Rochester Naturalist,' quarterly.
Sheffield : Sorby Scientific Society, 1918 (formerly Sheffield Nat. Club)	C. H. Wells, 80 Brookhouse Hill, Sheffield . .	130	None	5*s.*	Report, bi-annually; Proceedings, occasionally.
Somersetshire Archæological and Natural History Society, 1849	The Castle, Taunton. Rev. F. W. Weaver, C. Tite, and H. St. George Gray	925	10*s.* 6*d.*	Minimum 10*s.*6*d.*	Proceedings, annually.
South Africa, Royal Society of, 1906 . . .	G. M. Clark, South African Museum, Cape Town	207	None	2*l.*	Transactions, occasionally.
South-Eastern Union of Scientific Societies, 1896	H. Norman Gray, 334 Commercial Road, E. 1 .	about 13,000	None	Minimum 5*s.*	'South-Eastern Naturalist,' annually.
Southport Literary and Philosophical Society, 1880	W. Allanach, B.Sc., Victoria Science and Art Schools, Southport	186	None	7*s.* 6*d.*	Proceedings, occasionally.
South Staffordshire and Warwickshire Institute of Mining Engineers, 1867	G. D. Smith, 3 Newhall Street, Birmingham .	150	1*l.* 1*s.* and 10*s.* 6*d.*	2*l.* 2*s.* and 1*l.* 1*s.*	Transactions of Inst. of Mining Engineers, monthly.
Torquay Natural History Society, 1844 . .	Harford J. Lowe, F.G.S., The Museum, Torquay	175	None	1*l.* 1*s.*	Journal, annually.
Tyneside Geographical Society, 1887 . . .	Geographical Institute, St. Mary's Place, Newcastle-on-Tyne. Herbert Shaw, B.A.	1,000	None	1*l.* 1*s.* and 10*s.*	Journal, quarterly.
Vale of Derwent Naturalists' Field Club, 1887 .	J. E. Patterson, 2 East Avenue, Benton, Newcastle-on-Tyne	150	None	2*s.* 6*d.*	Transactions, occasionally.
Warrington Literary and Philosophical Society, 1870	J. S. Manson, M.D., 14 Bold Street, Warrington	140	None	5*s.*	Proceedings, biennially.
Warwickshire Naturalists' and Archæologists' Field Club, 1854	Museum, Warwick. C. West, Cross Cheaping, Coventry	70	None	5*s.*	Proceedings, annually.
Woolhope Naturalists' Field Club, 1852 . .	W. E. H. Clarke, Cathedral Chambers, King Street, Hereford	200	10*s.*	10*s.*	Transactions, occasionally.
Worcestershire Naturalists' Club, 1847 . .	Education Offices, Worcester. F. T. Spackman, F.G.S.	175	10*s.*	5*s.*	Transactions, annually.
Yorkshire Geological Society, 1837 . . .	Herbert E. Wroost, 45 Pollard Lane, Bradford .	184	None	13*s.*	Proceedings, occasionally.
Yorkshire Naturalists' Union, 1861 . .	The Museum, Hull. T. Sheppard, M.Sc., F.G.S	380 and 3,050 Associates	None	10*s.* 6*d.*	Transactions, annually; 'The Naturalist,' monthly.
Yorkshire Philosophical Society, 1821 . . .	Museum, York. C. E. Elmhirst. . .	500	None	2*l.*	Report, annually.

Associated Societies.

Balham and District Antiquarian Society, 1897 .	Miss M. Gardiner, 14A St. James' Road, Wandsworth Common, S.W. 17	86	None	5*s.*	Report, annually; Papers, occasionally.
Barrow Naturalists' Field Club and Literary and Scientific Association, 1876	W. L. Page, 5 Cavendish Street, Barrow . .	150	None	5*s.* and 2*s.* 6*d.*	Report and Proceedings, annually.
Battersea Field Club, 1894	Public Library, Lavender Hill, Battersea, S.W. 11. Miss L. B. Morris	54	2*s.* 6*d.*	3*s.* 6*d.*	—
Blackburn Naturalists' Field Club, 1909 . .	Joseph Smith, F.S.A.A., F.R.M.S, 27 Ainsworth Street, Blackburn.	109	None	2*s.* 6*d.*	Weekly reports in 'The Blackburn Times.'

Bradford Natural History and Microscopical Society, 1875	Fred. Jowett, Hummondale, Eldwick, Bingley .	75	1*s.*	4*s.*	—
Bradford Scientific Association, 1875 . . .	W. Newbould, 34 Burnett Avenue, Bradford .	100	None	5*s.* and 2*s.* 6*d.*	—
Catford and District Natural History Society, 1897	Thomas Coote, 25 Hawstead Road, Catford, S.E. 6	47	None	5*s.*	—
Dunfermline Naturalists' Society, 1902 . .	Robert Somerville, B.Sc., 31 Cameron Street, Dunfermline	160	None	5*s.*	—
Ealing Scientific and Microscopical Society, 1877	F. McNeil Rushforth, Ooley Lodge, 21 Florence Road, Ealing, W. 5	99	None	10*s.* and 2*s.* 6*d.*	Report and Transactions, annually.
Grimsby and District Antiquarian and Naturalists' Society, 1896	The Museum, Grimsby. A. Bullock (Acting Sec.)	60	None	2*s.* 6*d.*	—
Halifax Scientific Society, 1874	J. H. Lumb, 32 Undercliffe Terrace, Halifax .	183	None	2*s.* 6*d.*	—
Hastings and St. Leonards Natural History Society, 1893	W. de Muller, B.A., 14 St. Matthew's Gardens, St. Leonards-on-Sea	397	1*s.*	3*s.* 6*d.*	Report, annually. 'Hastings and East Sussex Naturalist,' occasionally.
Hawick Archæological Society, 1856 . . .	J. J. Vernon, 81 High Street, Hawick . . .	300	None	2*s.* 6*d.*	Transactions, annually.
Inverness Scientific Society and Field Club, 1875	Thomas Wallace, Ellerslie, Inverness . . .	160	None	5*s.*	Transactions, occasionally.
Lancashire and Cheshire Entomological Society, 1877	Royal Institution, Liverpool. William Mansbridge	90	None	5*s.*	Report and Proceedings, annually.
Leeds Naturalists' Club and Scientific Association, 1868	Edward J. T. Ingle, 18 Strattan Street, Leeds .	116	None	5*s.* and 3*s.* 6*d.*	Proceedings, occasionally.
Letchworth and District Naturalists' Society, 1908	W. Percival Westell, F.L.S., The Museum, Town Square, Letchworth	280	None	2*s.* 6*d.*	Occasional papers.
Lewisham Antiquarian Society, 1885 . . .	J. W. Brookes, Pembroke Lodge, Slaithwaite Road, Lewisham, S.E.	73	None	5*s.*	Transactions, occasionally.
Liverpool Microscopical Society, 1868 . . .	Royal Institution, Liverpool. R. Croston . .	63	None	10*s.* 6*d.*	Report, annually.
Llandudno and District Field Club, 1906 . .	L. S. Underwood, Brinkburn, Llandudno . .	120	None	5*s.*	Proceedings, annually.
London: London Natural History Society, 1913 .	Vernon Stuart, 78 Elgin Crescent, W. 11 . .	180 Members and Assoc.	2*s.* 6*d.*	7*s.* 6*d.* and 5*s.*	Transactions, annually.
London: South London Entomological and Natural History Society, 1872	Stanley Edwards, F.L.S., 15 St. German's Place, Blackheath, S.E. 3	160	2*s.* 6*d.*	10*s.*	Proceedings, annually.
Maidstone and Mid-Kent Natural History and Philosophical Society, 1868	Maidstone Museum. J. W. Bridge . . .	85	None	5*s.*	Report, occasionally.
Newcastle-upon-Tyne, Literary and Philosophical Society of, 1793	Newcastle-upon-Tyne. Alfred Holmes . .	4,000	None	1*l.* 1*s.*	Report, annually. Lectures, occasionally.
Preston Scientific Society, 1893	Lecture Hall, 119A Fishergate, Preston. F. Chadderton	400	None	5*s.*	Papers, occasionally.
Scarborough Philosophical and Archæological Society, 1828	A. J. Burnley, 43 Moorland Road, Scarborough .	60	None	1*l.* and 10*s.*	Report, annually.
School Nature Study Union, 1903	H. E. Turner, 1 Grosvenor Park, Camberwell, S.E.	1,350	None	2*s.* 6*d.*	'School Nature Study,' quarterly.
Southport Society of Natural Science, 1890 . .	P. H. Christian, 9 Russell Road, Southport . .	168	None	5*s.*	Report, biennially.
Teign Naturalists' Field Club, 1858 . . .	John S. Amery, Druid, Ashburton, Devon . .	120	None	2*s.* 6*d.*	Report, annually.
Tunbridge Wells Natural History and Philosophical Society, 1884	Dr. D. Davies, 8 Lonsdale Gardens, Tunbridge Wells	95	None	10*s.* 6*d.* and 5*s.*	Report, annually.
Warrington Society, 1898	The Old Academy, Bridge Foot, Warrington. James Richardson	105	10*s.* 6*d.*	1*l.* 11*s.* 6*d.*	Report, annually.
Watford Camera Club and Photographic Society, 1902	A. Dain, 100 High Street, Watford . . .	50	None	——	——
Wimbledon Natural History Society, 1911 . .	Charles H. Tame, 12 Kenwyn Road, S.W. 19 .	120	None	1*s.*	—

Catalogue of the more important Papers, especially those referring to Local Scientific Investigations, published by the Corresponding Societies during the year ending May 31, 1919.

*** This Catalogue contains only the titles of papers published in the volumes or parts of the publications of the Corresponding Societies sent to the Secretary of the Committee in accordance with Rule 2.

Section A.—Mathematical and Physical Science.

Alexander, Patrick Y. Aerial Communication. 'Report Royal Cornwall Polytechnic Soc.' iv. (n.s.) 79–83. 1918.

Alsop, J. C. Summary of Meteorological Observations and Meteorological Tables, 1918. 'Report Marlb. Col. N.H. Soc.' No. 67, 43–54. 1918.

Ashe, A. A New Incandescent Light for Microscopical Illumination. 'Journal Quekett Mic. Club,' xiv. 1–4. 1919.

Bassett, Rev. H. H. Tilney. Returns of Rainfall in Dorset in 1917. 'Proc. Dorset N.H.A.F.C.' xxxix. 76–84. 1918.

Campbell, J. W. The Deviations of Falling Bodies. 'Journal Royal Astr. Soc. Canada,' xii. 202–209. 1918.

Campbell-Bayard, Francis. Report of the Meteorological Committee, 1917. 'Trans. Croydon N.H. Sci. Soc.' viii. 175–184, and Appendices, 66 pp. 1918.

Cannon, J. B. The Orbit of Boss 1082. 'Journal Royal Astr. Soc. Canada,' xii. 210–213. 1918.

Cannon, J. B. The Spectroscopic Binary Boss 1275. 'Journal Royal Astr. Soc. Canada,' xiii. 55–56. 1919.

Chant, C. A. The Solar Eclipse of June 8, 1918 : Observations at Matheson, Colorado. 'Journal Royal Astr. Soc. Canada,' xii. 339–349. 1918.

—— Andrew Elvins (1823–1918). 'Journal Royal Astr. Soc. Canada,' xiii. 98–131. 1919.

Chree, Dr. C. Terrestrial Magnetism in relation to Mine Surveying. 'Trans. Inst. Min. Eng.' lv. 223–248. 1918.

Corless, R. Meteorological Instruments and how to use them. 'South-Eastern Naturalist for 1918,' 58–71. 1918.

Craw, James Hewat. Weather Notes, 1917. 'History Berwickshire Nat. Club,' xxiii. 432. 1919.

—— Amount of Rainfall in Berwickshire during the year 1918. 'History Berwickshire Nat. Club,' xxiii. 458. 1919.

De Lury, Ralph E. Simultaneous Variations in Solar Radiation and Spectroscopic Determinations of the Solar Rotation. 'Journal Royal Astr. Soc. Canada,' xii. 437–441. 1918.

—— Spectroscopic Measurements of the Solar Rotation at the Equatorial Limbs and at Points Midway between them and the Centre of the Solar Disc. 'Journal Royal Astr. Soc. Canada,' xii. 422–446. 1918.

Dodge, G. Blanchard. The Geodetic Comparator of the Dominion Lands Surveys Laboratory. 'Journal Royal Astr. Soc. Canada,' xii. 271–307. 1918.

DODGE, G. BLANCHARD. Magnetic Results, 1917. 'Journal Royal Astr. Soc. Canada,' XIII. 183–184. 1919.
DYSON, Sir F. W. The Determination of Stellar Distances. 'Journal Royal Astr. Soc. Canada,' XII. 195–210. 1918.
FAIRBROTHER, CHARLES J. (N. England Inst. Eng.). Record of Gas-pressure from a Borehole. 'Trans. Inst. Eng.' LVI. 6–8. 1918.
FOX, WILSON LLOYD, and JOSHUA BATH PHILLIPS. Report of the Observatory Committee of the Royal Cornwall Polytechnic Society, with Meteorological Tables and Tables of Sea Temperature for the year 1917. 'Report Royal Cornwall Polytechnic Soc.' IV. (N.S.) 18 pp. 1918.
FRANKLIN, A. V. The Moon and the Glacial Period. 'Journal Royal Astr. Soc. Canada,' XII. 450–452. 1918.
GARFORTH, Sir WILLIAM (Midland Inst. Eng.). High Temperatures in Deep Mines. 'Trans. Inst. Min. Eng.' LVI. 127–133. 1919.
HARPER, W. E. Nova Aquilæ No. 3. 'Journal Royal Astr. Soc. Canada,' XII. 268–270. 1918.
—— The Orbit of the Spectroscopic Binary *h* Draconis. 'Journal Royal Astr. Soc., Canada,' XII. 447–449. 1918.
—— The Spectrum of Nova Aquilæ, No. 3. 'Journal Royal Astr. Soc. Canada,' XII. 494–510. 1918.
—— Nu Geminorum, a Long Period Binary. 'Journal Royal Astr. Soc. Canada,' XIII. 179–182. 1919.
HASSARD, A. R. Astronomy in April. 'Journal Royal Astr. Soc. Canada,' XII. 214–216. 1918.
—— Venus, Jupiter, and Other Things. 'Journal Royal Astr. Soc. Canada,' XII. 363–366. 1918.
HODGSON, ERNEST A. Location of Epicentres for 1916. 'Journal Royal Astr. Soc. Canada,' XII. 251–267. 1918.
HUNTER, A. F. Some Special Forms of Halos. 'Journal Royal Astr. Soc. Canada,' XII. 427–436. 1918.
JACKSON, W. E. W. The Montreal Centre of the Royal Astronomical Society of Canada. 'Journal Royal Astr. Soc. Canada,' XII. 453. 1918.
KLOTZ, OTTO. Observatories in Canada. 'Journal Royal Astr. Soc. Canada,' XII. 217–224. 1918.
—— Light Pressure. 'Journal Royal Astr. Soc. Canada,' XII. 357–362. 1918.
—— The Dominion Astronomical Observatory at Ottawa. 'Journal Royal Astr. Soc. Canada,' XIII. 1–15. 1919.
LAWSON, GRAHAM C. Meteorological Report. 'Trans. N. Staff. F.C.' LII. 131–134. 1918.
LINGEN, J. STEPH. V. D. Notes on Radiation Patterns. 'Trans. Royal Soc. South Africa,' VII. 59–63. 1918.
MARKHAM, CHRISTOPHER A., and R. H. PRIMAVESI. Meteorological Report. 'Journal Northants N. H. Soc.' XIX. 151–154, 173–176, 192–196. 1918, 1919.
MARRIOTT, Major R. A. The Astronomical Clue to the Age of the Stone Implements in Kent's Cavern. 'Journal Torquay N.H. Soc.' II. 257–270. 1919.
MARTIN, E. A. Nature's Air-Raids: A Chapter in 'Meteoritics.' Presidential Address. 'Trans. Croydon N.H. Sci. Soc.' VIII. 151–159. 1918.
MILLER, A. F. Observing Mars with a Small Telescope. 'Journal Royal Astr. Soc. Canada,' XII. 191–194. 1918.
—— Nova Aquilæ, No. 3. 'Journal Royal Astr. Soc. Canada,' XII. 479–493. 1918.
—— A Review of Astronomy during 1918. 'Journal Royal Astr. Soc. Canada,' XIII. 81–97. 1919.
MOTHERWELL, R. M. Nova Aquilæ, No. 3. 'Journal Royal Astr. Soc. Canada,' XIII. 16–17. 1919.
MUIR, Sir THOMAS. Note on the Expansion of the Product of Two Oblong Arrays. 'Trans. Royal Soc. South Africa,' VII. 15–17. 1918.
—— Note on the Resolvability of the Minors of a Compound Determinant. 'Trans. Royal Soc. South Africa,' VII. 97–102. 1918.
—— Note on the Adjugate of Bezout's Eliminant of Two Binary Quantics. 'Trans. Royal Soc. South Africa,' VII. 199–202. 1919.
NELSON, EDWARD M. The Binocular Microscope. 'Journal Quekett Mic. Club,' XIII. 429–436. 1918.
—— A New Form of Polariser. 'Journal Quekett Mic. Club,' XIV. 19–22. 1919.

PICKERING, W. H. Distances of Two Star Clusters. 'Journal Royal Astr. Soc. Canada,' XII. 225–228. 1918.
PLASKETT, J. S. Notes on the Spectrum of Nova Aquilæ, No. 3. 'Journal Royal Astr. Soc. Canada,' XII. 350–356. 1918.
—— The Spectroscopic Binary H. R. 8170. 'Journal Royal Astr. Soc. Canada, XIII. 174–178. 1919.
RICE, JAMES. Discontinuity in the Phenomena of Radiation. 'Proc. Belfast N.H. Phil. Soc.' 1917–1918, 43–80. 1919.
SATTERLY, JOHN. Radiation and the Temperature of the Sun. 'Journal Royal Astr. Soc. Canada,' XIII. 33–44. 1919.
STEGMANN, E. T. The Torsion Problem for Bodies of Revolution. 'Trans. Royal Soc. South Africa,' VII. 147–180. 1919.
SUTTON, Dr. J. R. A Lunar Period in the Rates of Evaporation and Rainfall? 'Trans. Royal Soc. South Africa,' VIII. 103–109. 1918.
SWINTON, A. E. Meteorological Observations in Berwickshire for the year 1917. 'History Berwickshire Nat. Club,' XXIII. 457. 1919.
YOUNG, REYNOLD K. The Spectroscopic Binary 12 Lacertæ. 'Journal Royal Astr. Soc. Canada,' XIII. 45–54. 1919.

Section B.—CHEMISTRY.

DRAKELEY, THOMAS JAMES (Manchester Geol. Min. Soc.). The Relation between the Calorific Values and the Ash Yields of Coal-samples from the same Seam. 'Trans. Inst. Min. Eng.' LVI. 45–56. 1918.
EMBREY, GEORGE. Mineral Waters in and near Gloucester, with some Suggestions as to how the important Constituents have been formed. 'Proc. Cotteswold N.F.C.' XX. 29–43. 1919.
GRAHAM, J. IVON. The Origin of Blackdamp. 'Trans. Inst. Min. Eng.' LV. 294–303. 1918.
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Stress Distribution in Engineering Materials.—Report of the Committee, consisting of Professor J. PERRY (*Chairman*), Professors E. G. COKER *and* J. E. PETAVEL (*Secretaries*), Dr. A. BARR, Dr. CHAS. CHREE, Mr. GILBERT COOK, Professor W. E. DALBY, Sir J. A. EWING, Professor L. N. G. FILON, Messrs. A. R. FULTON *and* J. J. GUEST, Dr. B. P. HAIGH, Professors J. B. HENDERSON, F. C. LEA, *and* A. E. H. LOVE, Dr. W. MASON, Professor A. ROBERTSON, Dr. F. ROGERS, Mr. W. A. SCOBLE, Dr. T. E. STANTON, Mr. C. E. STROMEYER, *and* Mr. J. S. WILSON, *to report on certain of the more complex Stress Distributions in Engineering Materials.*

[PLATES V.–VIII.]

Introduction.

DURING the last five years many of the questions which had occupied the attention of the Committee have proved to be of considerable practical importance in connection with aircraft construction and engine design, and they have formed the subject of careful investigations initiated by the Air Board and the Navy.

At the present date much of the information is still regarded as confidential, but it is hoped to include a summary of this work in a subsequent report of the Committee.

The accurate determination of crippling load of struts is an important factor in the correct design of an aeroplane. Information is required with regard to struts of variable section, of uniform strength with or without lateral or eccentric loads. The questions have been treated theoretically by Barling, Cowley, Levy, Southwell, and Webb, and experimentally by Coker, Dalby, Lea, Robertson, and Scoble. Important investigations on the vibration of shafts and propellers have been made by Berry, Fage, Griffith, Jeffcott, Kerr, Morley, Southwell, and Webb, and methods of calculating the critical speed in complex cases have been solved.

Investigations on repeated stress have been carried out by Fulton and Lea, and also, in connection with several special problems, by various members of the N.P.L. staff. The question of the distribution of stress in wing structures of aeroplanes has also formed the subject of several papers; a summary of the work of Filon and Low is included in the present report.

In 1917 a very ingenious method of evaluating torsional and shearing stress by means of soap films was developed by Taylor and Griffith, which is an important advance on the earlier work of Prandtl; some details of this are given below.

During the war a number of systematic inquiries into cases of failure of various engine parts have been carried out by the R.A.F. A discussion of the information obtained will, it is understood, be published in due

course : the effect of surface scratches on the torsional strength of a shaft is of special interest. In connection more essentially with airscrew construction, the elastic constants of wood in the three principal directions have been determined, and the complex stresses arising in an airscrew due to thrust and centrifugal force have been studied by Berry, Griffith, and Hague.

The present report includes the following contributions :

'The Strength of Tubular Struts.' By Andrew Robertson, Major R.A.F., D.Sc. (Mc.).

'Investigations of Stresses in Aeroplane Wing Frameworks.' By Professor L. N. G. Filon, D.Sc., F.R.S.

'The Soap Film Method of Stress Estimation.' By A. A. Griffiths.

'Eccentric Loading in Tension and Compression Tests.' By W. A. Scoble.

'Experiments on the Effect of Alternations of Tensile Stress at Low Frequencies on the Elastic Properties of Mild Steel.' By Angus R. Fulton, M.B.E., B.Sc., A.M.Inst. C.E., Temp. Major R.A.F.

'The Strain-energy Function and the Elastic-limit.' By B. P. Haigh, M.B.E., D.Sc.

The Strength of Tubular Struts.

By Andrew Robertson, *Major R.A.F., D.Sc. (Mc.).*

The problem of the strength of a tubular strut differs from that of a solid strut in that there may be a condition of elastic instability in the wall of the tube under direct uniform compression. The theoretical analysis of Southwell [1] for this condition leads to the formula

$$p = \mathrm{E}\frac{t}{\mathrm{R}}\sqrt{\frac{m^2}{3(m^2-1)}}$$

where p = collapsing load per sq. in.
t = thickness of tube.
R = mean radius of tube.
$\frac{1}{m}$ = Poisson's ratio.
E = Young's modulus.

This formula applies only to cases in which the load per sq. in. is less than the elastic limit of the material, so that it cannot be expected to apply to any tube in which $\frac{t}{\mathrm{R}}$ is greater than $\frac{p}{\mathrm{E}\sqrt{\frac{m^2}{3(m^2-1)}}}$. For a mild-steel tube having an elastic limit of 20 tons per sq. in., $\frac{t}{\mathrm{R}}$ must be less than $\frac{1}{400}$, *i.e.*, if $t = \frac{1}{100}$" R must be greater than 4". Such tubes are never met with in practical work, so that the analysis suggests that all practicable tubes should sustain an average stress equal to the elastic limit before collapsing by wrinkling (the term used to denote the type

[1] R. V. Southwell, *Phil. Trans. Roy. Soc.* Series A. vol. 213.

of failure characteristic of tubes under compression, in which either wrinkles are produced in the walls or the wall 'caves in' in several places round the circumference).

When proper precautions are taken to secure accurate loading, experiments lead to the following conclusions for tubes of mild steel in which the elastic limit and yield are nearly identical.

(1) For tubes in which $\frac{t}{R}$ is greater than 0·006, yield precedes collapse by wrinkling.

(2) For tubes in which $\frac{t}{R}$ is greater than approximately 0·044, complete collapse occurs at higher stresses than the yield, whilst thinner tubes sustain the yield stress and collapse immediately by the walls 'caving in.'

It has been shown by the author that the yield stress in compression is the upper limit of strength for a strut of ductile material; hence it follows that the strength of a tubular strut in which $\frac{t}{R} > 0{\cdot}006$ is the same as that of a solid strut having the same $\frac{L}{K}$ and the same yield stress provided the end connections are satisfactory.

In all struts the strength is decreased by the effects of eccentricity of loading and initial curvature. For struts having free ends these can be readily allowed for by the following modification of Perry's formula:

$$p = \frac{p_y + (\eta+1)p_e}{2} - \sqrt{\left(\frac{p_y+(\eta+1)p_e}{2}\right)^2 - p_y p_e}.$$

p = average stress.
p_y = yield stress in compression.
p_e = Euler value.
$\eta = \frac{ca}{\kappa^2}$
a = distance of the extreme fibre from the centre of area of the cross-section.
κ = radius of gyration in plane of bending.
c = equivalent curvature = $c_1 + \frac{6}{5}h$.
c_1 = initial curvature = distance of the centre of area of the middle section from the line through the centres of area of the ends.
h = initial eccentricity of loading.

An alternative formula can be obtained by replacing the curvature term by an eccentricity term of the same amount, as suggested by Southwell, and using Smith's formula

$$p = \frac{p_y}{1 + \frac{\delta a}{\kappa^2}\sec\frac{l}{2}\sqrt{\frac{p}{E\kappa^2}}}.$$

δ = equivalent eccentricity = $h + c_1$.

From the examination of a large number of commercial tubes, Major Wylie suggests that reasonable values would be

$$h=\frac{\text{internal dia.}}{40} \qquad c_1=\frac{\text{Length}}{600}$$

Both the above formulæ agree well with the results of the author's experiments.

Investigations of Stresses in Aeroplane Wing Frameworks.

By Professor L. N. G. Filon, *F.R.S.*

A series of interesting experiments were carried out during 1918, in the Engineering Laboratory at University College, under the auspices of the Air Ministry. The experiments were carried out by Mr. Chakko and Air-Cadet McGowan, under the general supervision of Major A. R. Low, R.A.F., and Major L. N. G. Filon, R.A.F. An account of these experiments has been given by Major A. R. Low in the *Aeronautical Journal* for November 1918. The object of the investigation was to test a theory, due to Mr. Harris Booth and Mr. Harold Bolas, and further developed by Mr. Arthur Berry, for calculating the stresses in the frameworks carrying aeroplane wings. This theory, of which an account is being published in the Transactions of the Royal Aeronautical Society, contains an extension of Clapeyron's well-known theorem of Three Moments, so as to include the effects of bending moment due to end-thrust.

The fundamental assumption made in this theory is that the nodes of the framework, originally collinear and horizontal, remain collinear and horizontal when the load is applied, so that we can treat them, for mathematical purposes, as fixed points. The second half of the assumption—namely, that the nodes remain horizontal—is not essential, for we can, without sensible error to the order of approximation considered, measure deflections from the line of nodes. But the first assumption—namely, that the nodes remain collinear—is of primary importance. It really implies, unless a peculiar complex of values for the elastic constants of each element of the framework is postulated, that these elements, although capable of bending, cannot be materially stretched or compressed lengthways, so that, considered as a node-system, the framework is practically undeformable. Of course, if this were the case it would necessarily involve the truth of the other assumption, that the nodes remain horizontal.

The frameworks, considered generally, consist of two parallel horizontal continuous wing spars, connected by jointed struts and cross-wires, as shown in fig. 1, which is a photograph of the model actually used in the investigations. Of the cross bracing wires, only one-half really come effectively into play, the other half being reserved for use in peculiar conditions of flight, when for some reason the lifting surfaces of the wings are reversed, or to take the kinetic reactions on landing. Owing to the obliquity of these wires, discontinuities in the end thrust, as well as in the shear, are introduced at each node, but it is assumed that the bending moment is continuous as we pass through a node, and also that the central line of the beam is also continuous. The latter assumption is

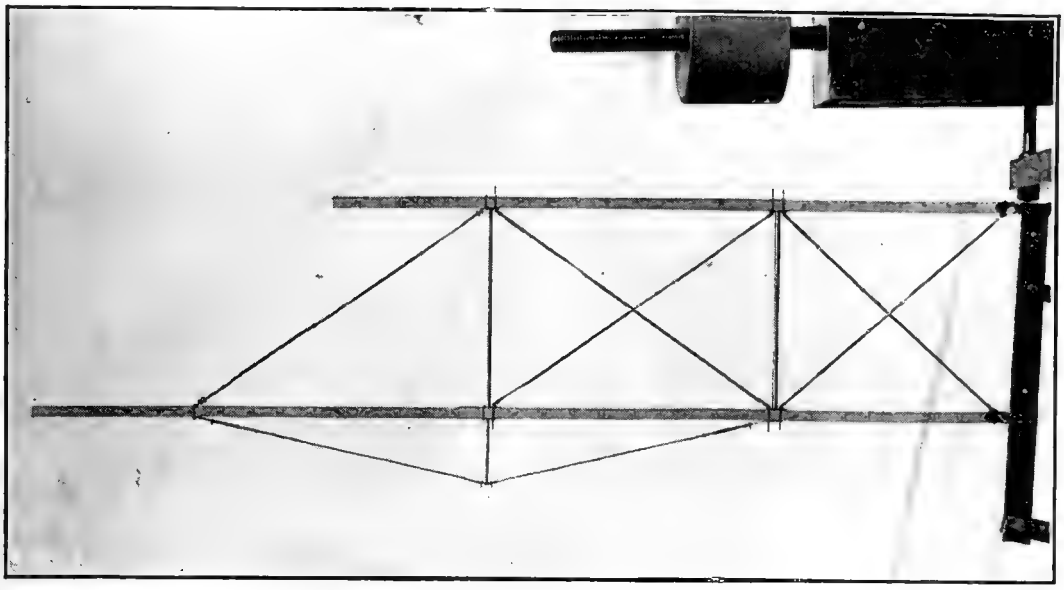

FIG. 1.

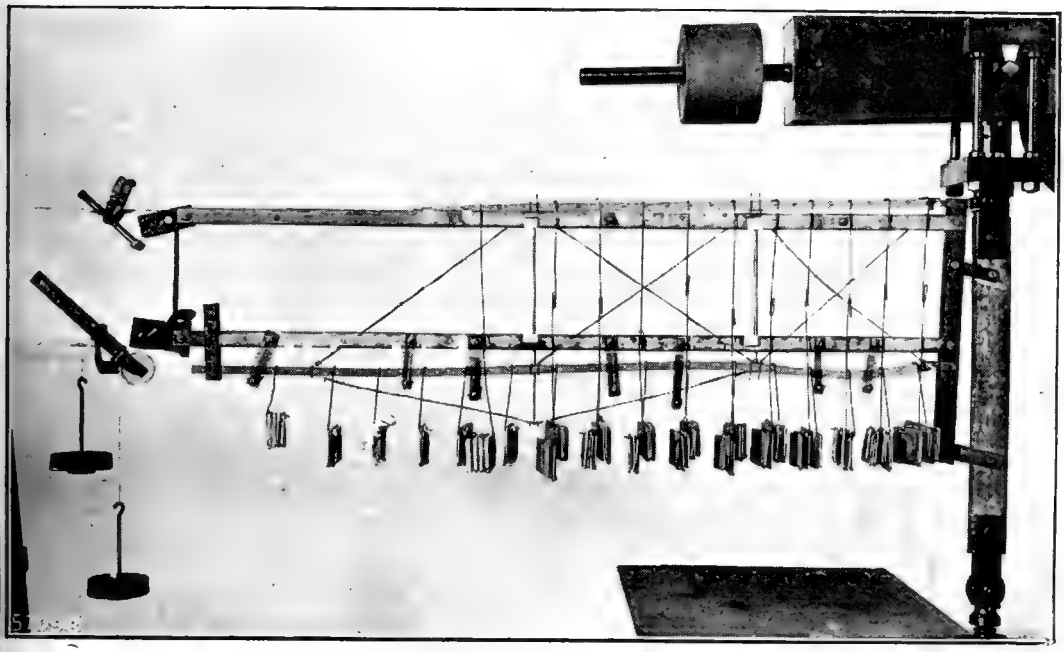

FIG. 3.

Illustrating the Report on Stress Distribution in Engineering Materials.

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generally made by engineers. It has been shown (L. N. G. Filon, *Phil. Trans.* A, vol. 201, pp. 84–86) to be mathematically incorrect; a certain definite amount of change of direction is introduced in a continuous beam as we pass a point of concentrated load, over and above that due to the Euler-Bernouilli curvature, but the deflection thus introduced is not equal to the so-called 'deflection due to shear' which is sometimes appealed to by engineers.

Neglecting, however, such changes in the slope of the central line and assuming the nodes fixed in position, consider a bay A, B (fig. 2), of length l, between two nodes.

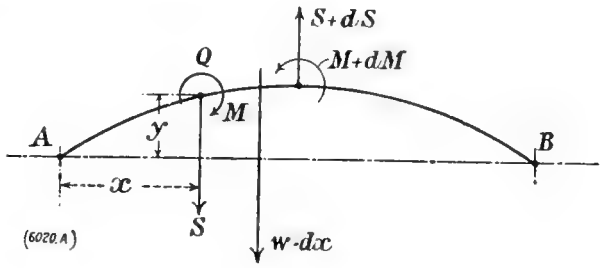

FIG. 2.

Let P be the thrust in this bay and let S, M be the shear, and bending moment at any point Q of the spar, x units to the right of A, at which the deflection is y.

Then, E being the Young's modulus and I the moment of inertia of the cross-section of the spar, w the load in lbs. weight per foot run, which will be assumed uniform, we have the following fundamental equations:

$$\mathrm{EI}\frac{d^2y}{dx^2}=\mathrm{M} \tag{1}$$

$$\mathrm{S}+\mathrm{P}\frac{dy}{dx}=-\frac{d\mathrm{M}}{dx} \tag{2}$$

$$\frac{d\mathrm{S}}{dx}=-w \tag{3}$$

whence

$$\frac{d^2\mathrm{M}}{dx^2}+n^2\mathrm{M}=w \tag{4}$$

where $\mathrm{P/EI}=n^2$

The solution of (1) and (4) is

$$\mathrm{M}=\alpha\sin nx+\beta\cos nx+\frac{w}{n^2},$$

$$\mathrm{EI}\,.\,y=-\frac{\alpha}{n^2}\sin nx-\frac{\beta}{n^2}\cos nx+\frac{wx^2}{2n^2}+\gamma x+\delta,$$

where α, β, γ, δ are arbitrary constants: these are determined from the conditions that $\mathrm{M}=\mathrm{M_A}$ when $x=0$, $\mathrm{M}=\mathrm{M_B}$ when $x=l$, $y=0$ when $x=0$ and $x=l$.

We find

$$\alpha = \frac{M_B - M_A \cos nl - \frac{w}{n^2}(1-\cos nl)}{\sin nl}$$

$$\beta = M_A - \frac{w}{n^2}$$

$$\gamma = \frac{1}{n^2 l}\left(M_B - M_A\right) - \frac{wl}{2n^2}$$

$$\delta = \frac{1}{n^2}\left(M_A - \frac{w}{n^2}\right)$$

Also

$$EI\left(\frac{dy}{dx}\right)_A = -\frac{\alpha}{n} + \gamma$$

$$= M_B\left(\frac{\sin nl - nl}{n^2 l \sin nl}\right) + M_A\left(\frac{nl\cos nl - \sin nl}{n^2 l \sin nl}\right)$$

$$+ \frac{w}{2n^3 \sin nl}[2(1-\cos nl) - ln \sin nl] \qquad (5)$$

If we now consider the bay immediately to the left, of which the end points are, say, B′ and A, and the length l' and in which the end thrust is P′, we have in general a new n'. If we suppose that the cross-section of the spar remains the same in each bay, we have, changing n into n' and l into $-l'$

$$EI\left(\frac{dy}{dx}\right)_A = -M_{B'}\left(\frac{\sin n'l' - n'l'}{(n')^2 l' \sin n'l'}\right) - M_A\left(\frac{n'l'\cos n'l' - \sin n'l'}{(n')^2 l' \sin n'l'}\right)$$

$$- \frac{w}{2(n')^3 \sin n'l'}[2(1-\cos n'l') - l'n' \sin n'l'] \qquad (6)$$

and since (5) and (6) must be the same,

$$M_B \frac{(\sin nl - nl)}{n^2 l \sin nl} + M_{B'} \frac{(\sin n'l' - n'l')}{(n')^2 l' \sin n'l'}$$

$$+ M_A\left(\frac{nl\cos nl - \sin nl}{n^2 l \sin nl} + \frac{n'l'\cos n'l' - \sin n'l'}{(n')^2 l' \sin n'l'}\right)$$

$$+ W\left[\frac{2(1-\cos nl) - ln \sin nl}{2n^3 \sin nl} + \frac{2(1-\cos n'l') - l'n' \sin n'l'}{2(n')^3 \sin n'l'}\right] = 0 \qquad (7)$$

which is the modified equation of the three moments. If we neglect end thrusts, that is make P and P′ approach zero and therefore also n and n' approach zero, then (7) approaches the limit

$$lM_B + l'M_{B'} + 2M_A(l+l') = \frac{w}{4}(l^3 + l'^3)$$

which is the theorem of three moments. (See Love's 'Elasticity,' p. 381.)

This modified theorem of three moments, together with the thrusts obtained by the ordinary theory of pin-jointed frameworks, enables the

bending moment and shear at each cross-section to be calculated, and hence the maximum tension and pressure in the spar.

A paper published by Messrs. Cowley and Levy ('Critical Loading of Struts and Structures,' R.S. Proc., Sec. A, vol. 94, pp. 405–422) gives an extension of the method of Booth, Bolas, and Berry to the case where the nodes are not all in one straight line, but makes the same assumption that the nodes remain fixed in position when the load is applied.

In the experiments described by Major Low, a model of a wing framework was constructed to scale, with the top and bottom spars of xylonite and the struts and cross-wires of steel. This model was then loaded by suspending a set of equally spaced leaden weights from the spars (see fig. 3, which shows the model loaded). Five amounts of total loading were employed—10, 20, 30, 35, and 40 lbs. weight. The stresses and deflections were calculated from the theory set forth above, in every case, save when the load was 40 lbs. weight, for which load the length of the bay considered exceeded Euler's limiting length for the ideal strut ($Pl^2/EI > \pi^2$). It has, however, been previously pointed out by Major Low himself ('Aeronautical Journal,' April 1914, p. 144) that the true criterion for instability in the case of a continuous beam is given by the length of spar between two successive points of inflexion lying in the same bay; Cowley and Levy, in their paper of 1918 (*loc. cit.*), merely state that the fact of Euler's length being exceeded in any one bay does not necessarily involve elastic instability, and this has been known for some time to other workers in this subject. Major Low's attention was called recently to this point, and he had his 1914 criterion applied to the example in question.[2] He then found that elastic instability had been theoretically reached for his greatest total load of 40 lbs., although the observations gave no evidence of any abrupt change of type in the equilibrium configuration. It has to be remembered, however, that in the experiments referred to the elastic-limit was passed before this value of the load was reached. The theory was then tested in two distinct ways:—(1) by measuring the actual deflections of the central line, calculating from these the curvatures and obtaining from the latter the bending moments and the stresses, (2) by direct observation of the stress, using the optical method described in the B.A. Report, 1914.[3]

The results are shown in Figs. 4–8, which are taken from Major Low's paper. The curves giving the calculated and observed deflections show significant discrepancies, especially for the higher loads. These discrepancies become striking when the deflection is measured from the line joining the nodes instead of from the horizontal. If this is done, the maximum deflection in the second bay is actually of opposite sign for the observed and calculated cases. Major Low suggests, on p. 31 of the paper referred to, that this is probably due to the fact that the inner bay of the upper spar was more severely strained and stressed than any other, with

[2] The criterion then becomes identical with that for elastic instability of a single strut, under uniform transverse load, whose terminal points coincide with the points of inflexion. It has been shown by Professor Perry (*Phil. Mag.* March 1892) and by Arthur Morley (*Phil. Mag.* June 1908) that for such a strut Euler's formula gives the condition of instability.

[3] 'Experimental Determination of the Distribution of Stress and Strain.' By Professors Filon and Coker, B.A. Report, 1914, pp. 201–210.

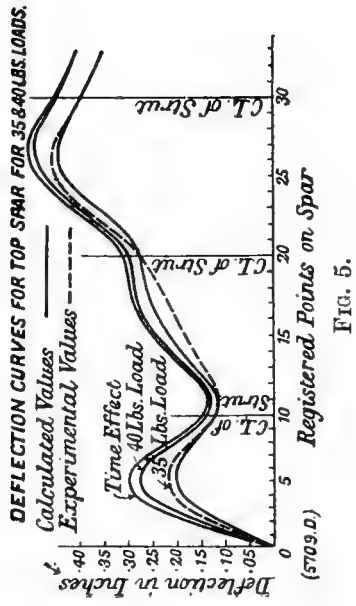

FIG. 5.

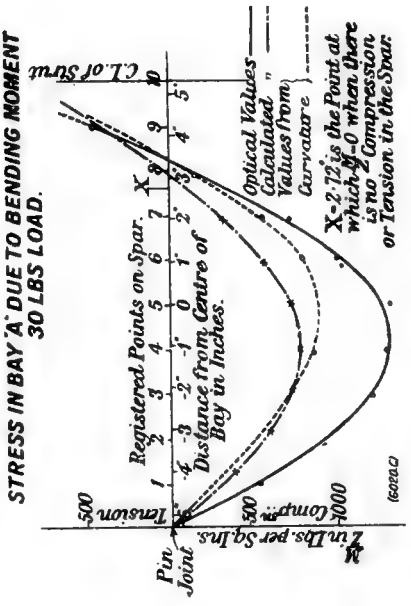

FIG. 7.

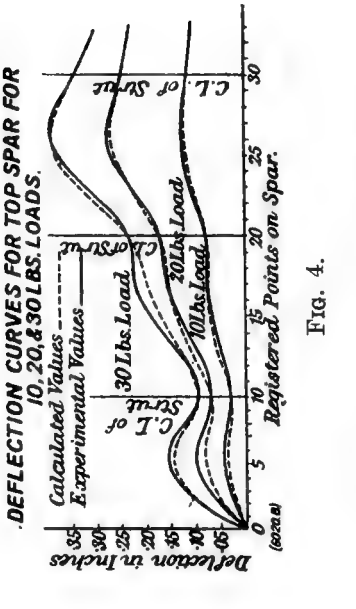

FIG. 4.

FIG. 6.

the result that the discrepancies in this bay were of the same order as the total deflection in the second bay, and it was therefore not surprising that the serious percentage difference between observed and calculated results in the first bay should be transmitted to the second bay in the form of discrepancies of the same order as the total deflection in the latter bay. He, therefore, limits his detailed comparisons to the first bay alone, and the curves of figs. 6, 7, and 8 refer exclusively to the stresses in this bay.

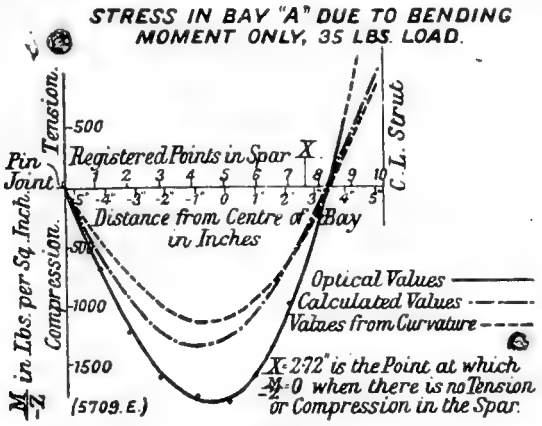

FIG. 8.

Even over this restricted range, the stresses determined by the three methods disagree among themselves to a considerable extent. It is not easy to see why there should be this disagreement between the values given by the optical method and those given by the curvatures. The obvious explanation, that the discrepancy is due to the spars having been over-strained (and that this undoubtedly occurred was shown by the 'creeping' or increase of both deflection and stress with time, without the load being increased, which was shown in both curvature and optical observations) is, unfortunately, disposed of by the following considerations :—

If we consider a rectangular strip under pure flexure of curvature

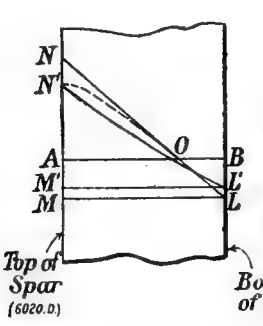

FIG. 9 (A).

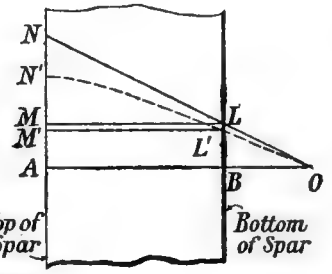

FIG. 9 (B).

1/R, the stretch at distance z from the neutral axis is z/R. Hence, the stress, calculated from the curvature is Ez/R.

Let AOB (Figs. 9 (A), 9 (B)) represent the trace of the cross-section of the spar on the central vertical plane of the beam.

O gives the position of the unstretched fibre which is inside the spar in fig. 9 (A) and outside it in fig. 9 (B). Owing to the existence of thrust, this may be anywhere. OL′N′ is the curve obtained by erecting, at each point of AOB, an ordinate representing the stress at that point. OLN is the tangent at O, to this curve, *i.e.*, it would represent the stress, if Hooke's law held throughout. L, L′, N, N′, are the intersections of this tangent and the curve, respectively, with the top and bottom of the spar. M, M′ are the projections of the L, L′ upon the opposite face of the spar.

Then $\frac{1}{2}$ MN = greatest stress due to bending moment only, as calculated from the curvature ; $\frac{1}{2}$ M′ N′ = greatest stress due to bending moment only, obtained from direct observations of stress in the extreme fibres, the usual law of stress across the section being assumed. It was in this way that the stress due to bending moment plotted in figs. 6, 7, 8 was obtained, viz. :—by taking the algebraic half difference of the stresses in the extreme fibres.

Now, owing to the well-known characteristics of the usual stress-strain diagram, the slope of the line L′ N′ is always less (whether in the case of fig. 9(B) or that of fig. 9(A)) than the slope of the line LN. It follows that M′N′ is always less than MN, that is, the stress calculated from the curvature should always be greater than the stress obtained directly from the optical observations. The exact opposite has apparently

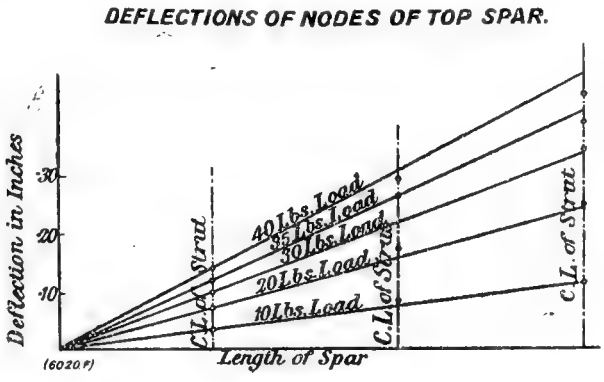

FIG. 11.

been observed, except precisely for the least of the loads for which curves are given.

Another conceivable explanation would be that the Young's modulus used in computing the stresses from the curvature was not correct. But this supposition is also negatived by the fact that some curves show the ' optical ' in excess of the ' curvature ' stress and others show it in defect.

It is most important that further experiments should be undertaken to resolve this discrepancy. Of course, it has to be borne in mind that the determination of curvature from a number of observations of deflection is necessarily very imperfect : at the same time, it is interesting to note that in the determination of the points of inflexion, where the curvature vanishes, the method of deflections and the optical method give results which agree

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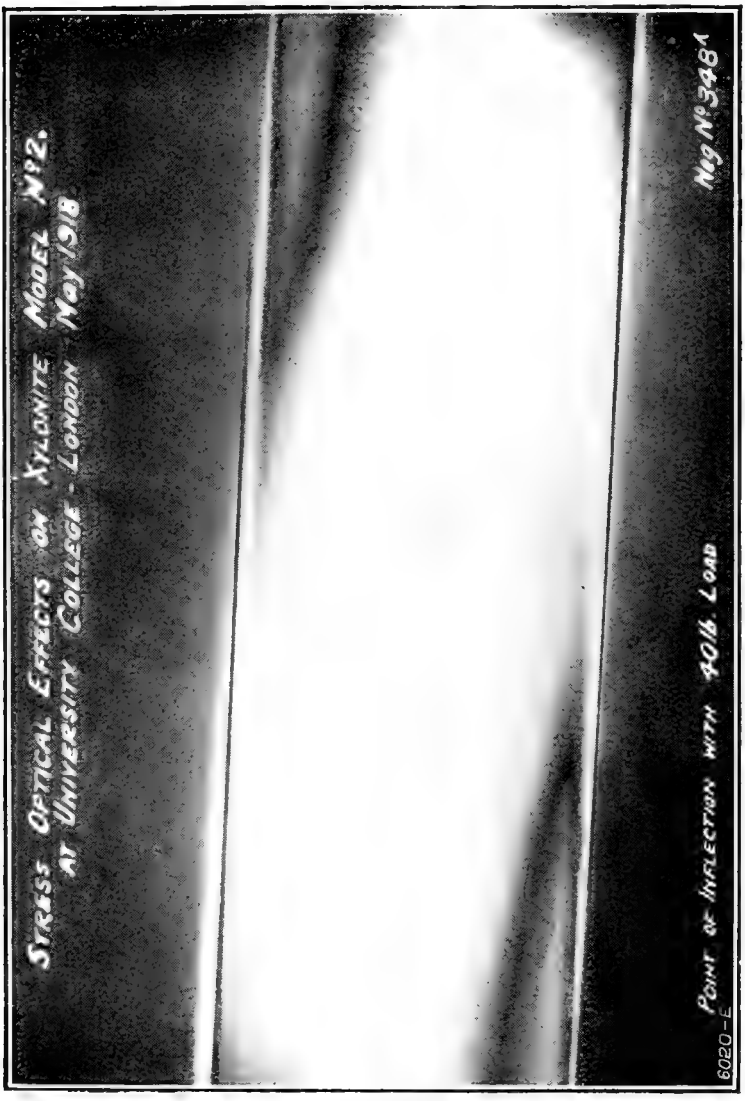

FIG. 10.

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closely. A point of inflexion is very readily determined by the optical method, the appearances in such a case being as shown in fig. 10. A wrong calibration factor for the test piece used in the optical measurements might account for the discrepancies of figs. 6 to 8, but this, again, seems unlikely, as it would involve a progressive variation of this calibration, which is hardly reconcilable with a numerical oversight.

Passing now to the discrepancies with the theory, Major Low has given (fig. 11) a diagram showing the observed deflections of the nodes: this makes it clear that the fundamental assumption of the theory, that the nodes remain collinear, is not tenable, and this is probably quite sufficient to account for the observed divergencies, about which—especially as regards the shift of the point of inflexion—there seems to be no doubt.

Note on the Principle of Dynamical Similarity applied to Deformable Elastic Structures.

By Professor L. N. G. Filon, *F.R.S.*

1. *General case of structure of finite thickness.*

Consider any deformable structure subjected to strain. Let a mechanical model of this structure be made accurately to scale, but of different material. We will investigate the relations which have to be satisfied by the elastic constants and the stresses applied if the deformations of the original system and of the model are to be geometrically similar. Let k be the ratio of similarity of the model and the original, so that if l be any length in the original, kl is the corresponding length in the model.

If x, y, z are the co-ordinates of any point of the original (kx, ky, kz) are the co-ordinates of the corresponding point of the model.

If (u, v, w) are the displacements at (x, y, z), (ku, kv, kw) are the displacements at (kx, ky, kz).

The *strains*

$$s_x = \frac{\partial u}{\partial x},\quad s_y = \frac{\partial v}{\partial y},\quad s_z = \frac{\partial w}{\partial z}.$$

$$\sigma_{yz} = \frac{\partial v}{\partial z} + \frac{\partial w}{\partial y},\quad \sigma_{zx} = \frac{\partial w}{\partial x} + \frac{\partial u}{\partial z},\quad \sigma_{xy} = \frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}$$

are identical in the model and original.

The *stresses* are given by

$$\widehat{xx} = \lambda\left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z}\right) + 2\mu\frac{\partial u}{\partial x};\ \text{and two similar equations}$$

$$\widehat{yz} = \mu\left(\frac{\partial v}{\partial z} + \frac{\partial w}{\partial y}\right);\ \text{and two similar equations, } \lambda \text{ and } \mu, \text{ being the}$$

elastic constants of Lamé.

Thus, in general, for dynamical similarity, all the elastic constants have to be altered in the same ratio q, and the applied stresses must be altered also in the ratio q.

2. *Framework of thin rods.*

In the case of *thin* rods forming part of a plane framework under stress in its own plane, we have, if T be the total tension and M the bending moment at any point of a rod, and T′, M′ the corresponding quantities in the model,

$$T = E\Delta s;$$
$$T' = E'\Delta' s'.$$

when s, s' are the longitudinal strains of the rod in the full size and model, respectively.

E, E′ are the Young's Moduli, Δ, Δ' the cross-sections of the rods.

Now $s = s'$ by geometrical similarity.

Hence $T : T' = E\Delta : E'\Delta'$ (1).

Further

$$M = \frac{EI}{R}$$

where I is the moment of inertia of the cross-section of the rod about its neutral axis and R is the radius of curvature of the rod.

Similarly

$$M = \frac{E'I'}{R'}$$

where clearly $R' = kR$ by geometrical similarity. Also, let p be the ratio of forces (*not* stresses) in the model and full size.

Then $M' = Mpk$, *i.e.*,

$$E'I'/R' = pk\ (EI/R)$$

and $E'I'/EI = pk^2$. (2)

But from (1) since $T' = pT$

$$\frac{E'\Delta'}{E\Delta} = p. \qquad (3)$$

From (2) and (3) by division

$$\frac{I'/\Delta'}{I/\Delta} = k^2 \qquad (4)$$

Let K be the swing radius of the cross-section of any rod in the full size, and K′ in the model.

Then $I = K^2\Delta$

$$I' = (K')^2\Delta'$$

(4) then gives $(K')^2/K^2 = k^2$

or $K' = kK$ (5)

That is, although the cross-sections need not be geometrically similar (the rods being *thin*), the radii of gyration of the cross-sections *must* be in the ratio of *geometrical* similarity k.

This condition being once satisfied, equation (3) shows that the moduli $E'\Delta'$, $E\Delta$ for the rod, as a whole, must be in the ratio of *dynamical* similarity p, *i.e.*, in the ratio of the applied forces.

Now k will usually have to be fixed beforehand ; k being known, the radius of gyration K' in the model is fixed.

The materials of the model are also usually not at our choice. Thus E' is fixed. But Δ' can be varied within large limits, and this without altering k. An easy example of this is when the bars of the model are rectangular in section.

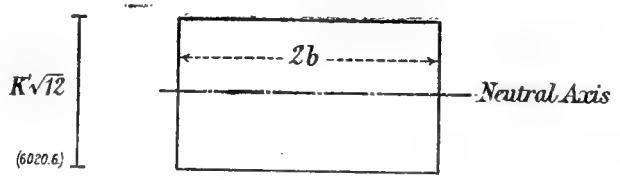

FIG. 12.

The height of the cross-section $= K'\sqrt{12}$ and is therefore fixed. But the breadth $2b$ is at our disposal and can be varied, so that Δ' satisfies equation (3).

An important particular case occurs when certain rods or ties of the full size are practically unyielding or inextensible, at any rate, in comparison with the others. In this case, E is infinitely great and E′ must also be infinitely great. All that is necessary then is to make the corresponding bars of the model likewise unyielding or inextensible in comparison. Provided this is done, we need only trouble to satisfy the conditions for the ' yielding ' or soft parts of the model and full size.

If the model and full size are made up of *two* kinds of material only—a ' yielding,' and an ' unyielding '—it will usually be convenient to satisfy equation (3) by adjusting p, the ratio of dynamical similarity, that is, by applying suitable loads to the model instead of altering the cross-sections to the right ratio.

(3) *Safety conditions for the model.*

The question of breaking stress on the model is one of fundamental importance. For we have to be careful that the stresses imposed in conserving similarity shall not be so great as to cause the model to collapse.

We have, y and y' being the distances from the neutral axes of the outermost fibres in full size and model respectively, the greatest stresses as follow :—

$$Es + \frac{Ey}{R} \text{ (full size)} ;$$

$$E's' + \frac{E'y'}{R} \text{ (model)} ;$$

(numerically positive values being taken for each quantity).
Now $s' = s$, $R' = kR$; but y' is not equal to ky in general.

As, however, $K' = k K$, in the case of *rectangular* bars $y' = ky$ accurately, and it is not unreasonable to suppose that y' will generally be of the order ky. (Note for *similar* sections $y'=ky$ also.)
Thus, we may take the case of rectangular bars as fairly typical.

We have then $\frac{y}{R} = \frac{y'}{R'}$ and

greatest stress in model : greatest stress in full size
$= E' : E.$

That is :
greatest *strain* in model = greatest *strain* in full size.

Hence, the greatest strain to which the material of the full size is subjected in the case considered must not break down the material of the model.

If the model is made of much more yielding material than the full size, the material of the model will, as a rule, stand a much greater strain than that which would break material of the corresponding full-sized member.

Xylonite is a much more yielding material than wood. So that if the full-size spar is of wood and the model of xylonite, the conclusions of the last paragraph hold good. Loads on the xylonite model will still usually be well within the safety limit, even when the corresponding loads on the full-size wooden member exceed the safety limit, a point of great value in investigating dangerous stresses.

The Soap Film Method of Stress Estimation.

By A. A. Griffiths.

The use of soap films in the determination of elastic stresses and strains depends on the mathematical similarity between certain forms of the general equations of elasticity and the equation of the surface of a soap film slightly displaced from a plane.

The latter equation may be taken to be

$$\frac{\partial^2 z}{\partial x^2} + \frac{\partial^2 z}{\partial y^2} + \frac{P}{2s} = 0$$

where the plane is that of x, y, p is the pressure difference between the two sides of the film, and s is the surface tension. Any two-dimensional elastic problem in which the dilation, or the sum of the principal stresses, is a known function of x and y may, by known mathematical methods, be made to depend on the solution of an equation of this type. This is the most general form of elastic problem which can be solved directly by means of soap films.

The solution is obtained by forming a film, which satisfies the conditions of the problem, and taking the required measurements from it by means of special appliances. The most useful of these are

(*a*) The spherometer, which is a needle, moistened with soap solution, which can be moved at will in any desired plane parallel to the plane of x, y. This is caused to touch the film at a series of points, whose positions are recorded by a simple copying mechanism. In this way a complete contour map of the film surface may be obtained.

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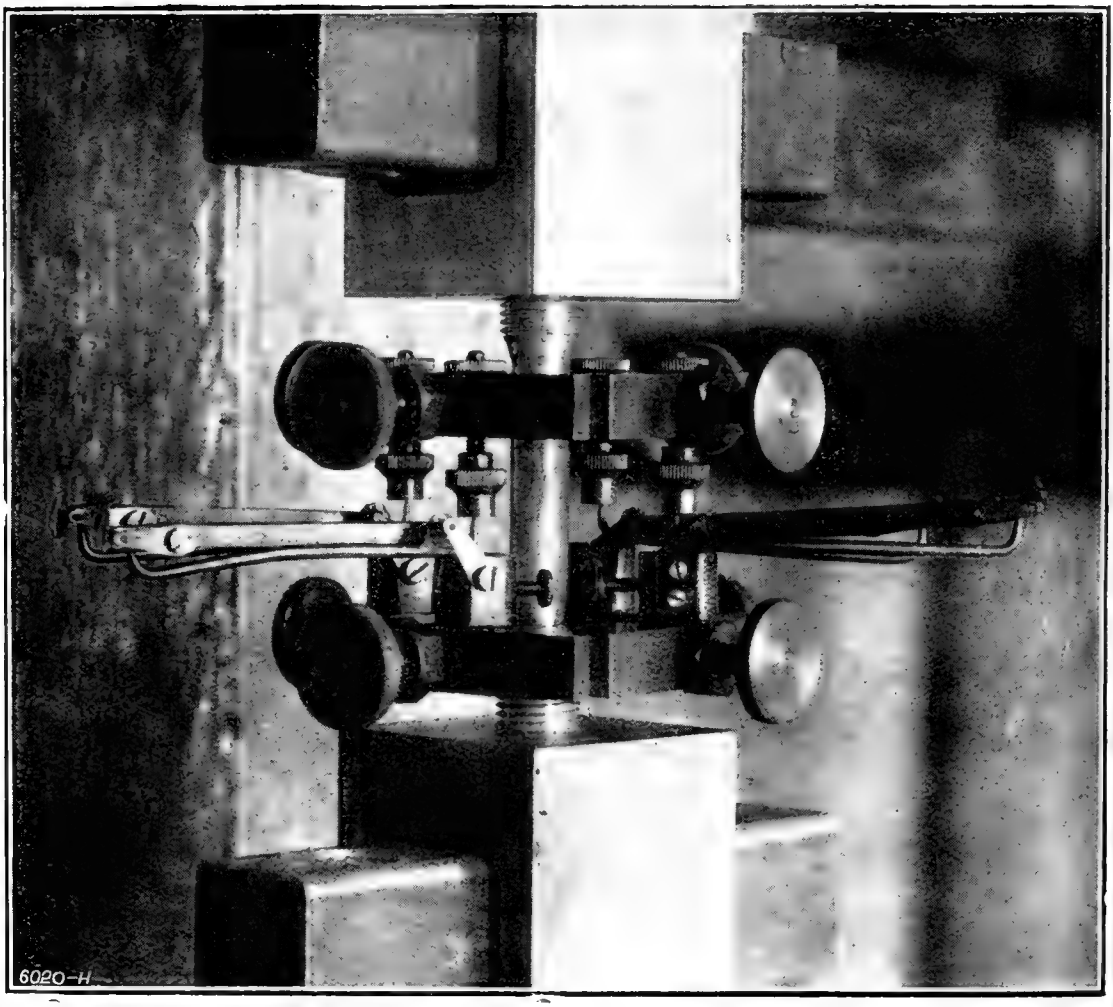

FIG. 13. EXTENSOMETER.

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(*b*) The auto-collimator, which measures the slope of the film at any desired point by an optical reflection method.

The most important practical problem which may be solved by this method is that of the torsion of a cylinder, or beam of uniform cross-section. In this case, the dilation is zero, and the appropriate soap film may be formed on a hole, in a flat plate, of the same shape as the cross-section of the beam. The film is slightly displaced from the plane of the plate by maintaining a small excess of pressure on one side of it. The slope of the film at any point is proportional to the stress at that point, the direction of the contour lines is the direction of the stress, and the volume between the film and the plane of the plate is proportional to the torsional stiffness of the beam. The constants of proportionality are obtained by comparison with a circular film under the same pressure difference.

Sections of any shape whatever may be dealt with, but in the case of hollow beams the inner boundary or boundaries must be parallel to, but not coincident with, the outer one. The proper relative positions may be found by measuring auxiliary soap films.

A further problem of considerable practical importance, which may be solved by the soap film method, is the determination of the shearing stresses in a bent beam. In this case, the hole representing the boundary must be cut in a curved plate, the shape of the elevation of the edge being calculated from the dimensions of the section. This film is not blown up. The components of shearing stress are calculated from the components of the slope of the film, in the directions *ox* and *oy* respectively. The twist of the beam, under a load applied at any given point, may also be found.

The following papers deal with the subject :

(1) 'The Use of Soap Films in Solving Torsion Problems.' *Proc. Inst.Mech.E.*, December 14, 1917.

(2) Reports of the Advisory Committee for Aeronautics :—
R. & M. 332, R. & M. 334, T. 1040, T. 1076, T. 1275.

Eccentric Loading in Tension and Compression Tests.

By WALTER A. SCOBLE.

The earlier tests were made to determine the degree of variation of stress across the section of a specimen subjected to tension or compression. Different arrangements for the application of the load were tried, and the specimens were prepared from various materials.

The effect of the eccentric loading was surprisingly pronounced, and a further series of experiments was made on different metals to estimate the effect on the test results of the unequal stress distribution across the section of the specimen.

A distinction must be drawn between the two series of tests. The first set represents conditions which are realised in practical testing, but for the second series the load was occasionally purposely made eccentric to yield evidence of the effect of bending on the behaviour of the metal under test.

The extensometer used (fig. 13) consisted of two independent clamps attached to the specimen by pointed screws. The lower clamp carries

four self-contained, double-lever, strain-measuring units. A scale division represents about three-millionths of an inch change of length of the specimen, but less sensitive elements are used for materials which have low values of 'E.' The test length is usually 1·5 inches.

Three measurements are sufficient to allow the strain distribution across the section of the test piece to be calculated, but the fourth introduces no further complication and allows a useful check to be made, or avoids the scrapping of a series of readings if one element deflects beyond the limit of its scale.

Typical plottings of the four measurements against the loads are given in fig. 14 as an example of very eccentric loading, and in fig. 15 to show the best result realised in practice.

Variation of Strain across the Section of a Test Piece.

The first results are collected to indicate the variation of the strain across the section of a specimen. The usual precautions were observed for the type of test considered. The strain distribution usually alters somewhat with the load, so the figures tabulated have been taken for the region of the elastic limit, or, when the load was not taken so high as this, for the greatest load applied.

Tension Tests. Solid Specimens.

Number	Material	Condition	Method of Loading	Maximum Strain / Mean Strain
S2. 2	Mild steel	Not annealed	Wedge grips	1·242
SC. 1	,, ,,	,, ,,	,, ,,	1·214
SC. 5	,, ,,	,, ,,	,, ,,	1·170
HP. 28	38 ton steel	,, ,,	,, ,,	1·158
HP. 35	,, ,,	,, ,,	,, ,,	1·016
S.1. 4	Cast steel	,, ,,	,, ,,	1·086
S.1. 5	,, ,,	,, ,,	,, ,,	1·160
S.1. 10	,, ,,	,, ,,	,, ,,	1·137
SC.4. 1	Mild steel	Annealed	,, ,,	1·620
SC.4. 2	,, ,,	,,	,, ,,	1·585
BA1. 6	,, ,,	,,	,, ,,	1·104
BA1. 7	,, ,,	,,	,, ,,	1·273
S2. 3	,, ,,	,,	,, ,,	1·328
S2. 6	,, ,,	,,	,, ,,	1·415
S2. 7	,, ,,	,,	,, ,,	1·533
SC. 2	,, ,,	,,	Screwed ends	1·161
BA1. 1	,, ,,	,,	,, ,,	1·068
BA1. 8	,, ,,	,,	,, ,,	1·106
S2. 5	,, ,,	,,	,, ,,	1·062
S1. 2	Cast steel	,,	Wedge grips	1·018
S1. 7	,, ,,	,,	,, ,,	1·162
BC. 1	Brass rod		Screwed ends	1·080
BC. 2	,, ,,		Wedge grips	1·261
AB. A1	Aluminium bronze	As cast	Screwed ends	1·127
AB. A.2	,, ,,	,, ,,	,, ,,	1·100
AB. B.1	,, ,,	,, ,,	,, ,,	1·360
AB. B.2	,, ,,	,, ,,	,, ,,	1·390
100 A.2	Aluminium alloy	,, ,,	Robertson's Ball Loading	1·052
100 A.3	,, ,,	,, ,,	,, ,, ,,	1·140
100 A.4	,, ,,	,, ,,	,, ,, ,,	1·077

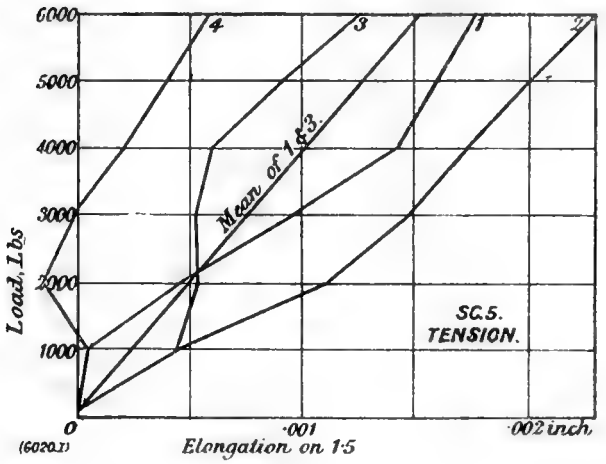
6000
5000
4000
3000
2000
1000
Load, Lbs
4
3
1
2
Mean of 1 & 3.
SC.5.
TENSION.
0
(6020.1)
·001
·002 inch.
Elongation on 1·5

FIG. 14.

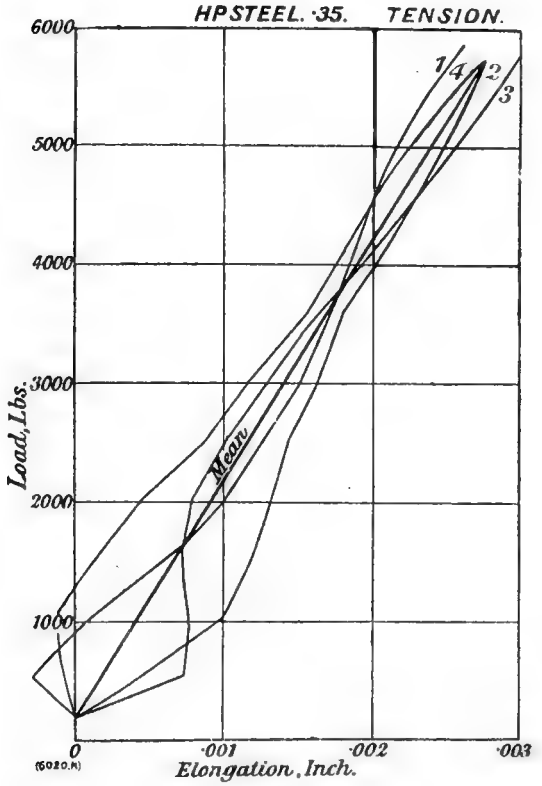
HPSTEEL. ·35. TENSION.
6000
5000
4000
3000
2000
1000
Load, Lbs.
1/4
2
3
Mean
0
(6020.8)
·001
·002
·003
Elongation, Inch.

FIG. 15.

Tension Tests of Tubes.

Specimen	Method of Loading	Maximum Strain / Mean Strain
Steel tube $\frac{3}{4}$ inch 22*g*.	Coned tube grips	1·156
,, ,, ,, ,, ,,	,, ,, ,,	1·155
Aluminium $\frac{3}{4}$,, 16*g*	,, ,, ,,	1·187
,, ,, ,, ,,	,, ,, ,,	1·090
,, $\frac{1}{2}$ inch 16*g*	Ends flattened, wedge grips	1·160
Steel streamline. $1\frac{1}{2} \times \frac{3}{4} \times 20g$	,, ,, ,, ,,	1·454
Aluminium alloy $\frac{3}{4}$-inch	Coned tube grips	1·055

Compression Tests.

Material	Form	Method of Loading	Maximum Strain / Mean Strain
Spruce	Tube o.d. 1·36 inch i.d. ·75 ,,	Through ball on steel cap	1·205
Aluminium alloy	Solid 1·44 inch diam.	Through ball on turning centre	1·058
,,	,, 1·35 ,, ,,	Through ball on steel cap	1·706
,,	,, ,, ,, ,,	,, ,, ,, ,,	1·110
Mild steel	Solid, annealed ·78 inch diam.	Through ball on turning centre	1·142
Aluminium alloy	Solid 1·07 inch diam.	,, ,, ,, ,, ,,	1·095
,,	,, ·70 ,, ,,	,, ,, ,, ,, ,,	1·352
Steel	Streamline Tube	Through ball on steel cap	1·362

The results show that the variation of strain, and therefore of stress, across the section of a test piece is usually appreciable and is sometimes of considerable magnitude.

For plain ended tension specimens of mild steel held by wedge grips, the maximum exceeds the mean strain by an average value of 16 per cent., reaching 24·2 per cent. in one case. For cast steel, similarly gripped, the corresponding figures are 12·8 and 16 per cent. The serrated wedges appear to bite more deeply into annealed mild steel, and the figures rise to 40·8 and 62 per cent. This inequality is so great that it is rather startling, but it is reduced for similar specimens to 9·9 and 16·1 per cent. by the adoption of screwed ends. There is no evidence of a corresponding inaccuracy due to wedge grips after a high carbon steel is annealed.

Rod brass and aluminium bronze gave results which are in general agreement with those summarised above, but in one case the bronze with screwed ends showed maximum strains 36 per cent. and 39 per cent. greater than the mean. It appears probable that here the inequality is due rather to lack of homogeneity of the material than to eccentricity of loading, and the same explanation may be given to account for the variations with the accurately constructed Robertson loading device used in some of the experiments.

The Effect of Eccentric Loading on the Elastic Limit and Yield Point.

Eccentric loading would be of no importance if it did not affect the test results. The elastic-limit, yield-point, and maximum stresses should all be considered to determine the effect upon them. It may be noted

that if there is appreciable yield before fracture it is to be expected that the stress on a section of a tension or compression specimen is equalised, and that the mean maximum stress is not appreciably affected by a probable amount of eccentricity in the loading.

The test results are tabulated below, according to the material, to compare the stresses at the elastic-limit, yield-point, and maximum load. The elastic-limit stress, calculated by dividing the load by the area of the cross-section, is also corrected in the ratio of the maximum to the mean strain.

Specimen	Annealed or not	Maximum Strain. Mean Strain	Elastic Limit Stress Direct tons/s.inch	Elastic Limit Stress Corrected tons/s.inch	Yield Stress tons/s.inch	Maximum Stress tons/s.inch
Mild Steel	not					
S2.2	,,	1·242	21·1	26·2	21·1	25·6
SC. 5	,,	1·170	14·9	17·45	15·5	21·9
HP. 28	,,	1·158	25·0	28·95	26·7	38·7
HP. 35	,,	1·016	23·66	24·04	26·6	38·5
Mild Steel	Annealed					
SC. 2	,,	1·161	11·16	12·97	12·5	20·6
SC. 2	,,	4·40	4·56	20·1	11·9	20·75
SC. 4	,,	1·620	8·55	13·85	12·65	—
SC. 4	,,	1·585	9.32	14·78	14·05	20·8
BA1. 1	,,	1·068	10·04	10·72	10·04	20·8
BA1. 6	,,	1·104	14·31	15·83	17·55	23·6
BA1. 7	,,	1·273	13·48	17·15	17·35	23·8
BA1. 8	,,	1·106	15·24	16·86	17·17	24·0
S2. 3	,,	1·328	9·06	12·03	10·07	20·9
S2. 5	,,	1·062	10·03	10·66	10·30	22·0
S2. 6	,,	1·415	8·52	12·05	12·49	21·9
S2. 7	,,	1·533	7·41	11·35	11·73	21·7
Cast Steel	not					
S1. 4	,,	1·086	18·14	19·7	26·3	51·5
S1. 5	,,	1·160	23·5	27·2	23·5	51·8
S1. 10	,,	1·137	20·44	23·22	24·0	53·0
Cast Steel	Annealed					
S1. 2	,,	1·018	19·0	19·3	19·6	46·9
S1. 7	,,	1·162	16·9	19·65	19·8	—
Steel Tube	$\frac{3}{4}$-inch	1·156	15·6	18·03	—	44·1
,, ,,	,,	1·155	15·62	16·04	—	43·6
Aluminium tube		1·187	6·69	7·93	—	13·1
,, ,,		1·090	5·68	6·19	—	—
,, ,,		1·160	6·40	7·42	—	12·8
Cast Aluminium	Bronze A	1·127	13·10	14·75	—	40·4
,,	,,	1·100	12·73	14·0	—	41·7
,,	Bronze B	1·36	4·46	6·06	—	30·7
,,	,,	1·39	6·10	8·50	—	—
Rod Brass	BC. 2	1·261	9·64	12·15	—	34·4
,, ,,	,, 1	1·08	11·07	11·95		34·8

In order to judge whether the stresses should be corrected in the ratio of the variation of strain, the values at the elastic limit for the same material can be compared amongst themselves, and with the yield point stresses.

The adjustment is not justified for unannealed mild steel. In the case of S2. 2 the elastic-limit and yield-point coincided. The correction makes the elastic-limit greater than the maximum stress. For Sc. 5 and HP. 28

the corrected E.L. stresses are much greater than those at the corresponding yields.

There is no doubt that inaccurate loading lowers the mean elastic limit stress in the case of annealed mild steels, and that its true value varies somewhat. The two samples SC. 4 show approximately the same stress distribution, but the E.L. stresses are 8·55 and 9·32 tons per sq. in. before correction. BA. 1, 6, and 7 afford an even better example because the higher E.L. accompanies the lower Y.P. stress.

Evidently the measured E.L. stresses need some correction to give true values, but it seems that that indicated by the strain distribution is too drastic if the eccentricity of loading be large, *e.g.*, SC steel. Of the BA specimens 7 and 8 agree fairly well after correction with each other and with the yield stresses, but for 6 the value is still low. The S2 steel shows similar inequalities, 3 and 5 are over-corrected, but for 6 and 7 the results are fairly good.

It is desirable to remark that too close agreement cannot be expected between values for stresses at the elastic limit, nor at yield when the stress is unequally distributed. In general, the stress-strain curve does not diverge greatly from a straight line at first, and, since small errors of observation arise, it is not easy exactly to locate the required point.

Cast steel as supplied in the bar gives results which are not improved by the suggested correction, but the annealed specimens need it.

The values for aluminium and the bronzes are in no better agreement after the adjustment.

Only two specimens of brass rod are included, but these show the best agreement of all between the corrected E.L. stresses.

Unfortunately, it is not possible to draw many general conclusions from the data available. Only in the cases of annealed steels and brass is the proposed correction of the elastic limit stress, in the ratio of maximum to mean strain, at all justified, and then the factor is too large if the inaccuracy of loading is considerable.

The degree of eccentric loading which is likely to arise in tension-testing has less effect on the yield point stress than the differences which are found along the same bar, and, as was expected, there is no evidence of the maximum stress being affected.

Should the elastic limit of a steel or the yield point of other material be required, it is necessary to take precautions to ensure that the loading is accurate, and thus minimise the necessity for correction, which latter cannot be applied in any case with certainty.

Experiments on the Effect of Alterations of Tensile Stress at Low Frequencies on the Elastic Properties of Mild Steel. *By* Angus R. Fulton, *M.B.E., B.Sc., A.M.Inst.C.E., Temp. Major Royal Air Force.*

The work was carried out in the Engineering Laboratory of University College, Dundee. It was directed to several points raised in the investigations into the theory of failure due to repetitions of stress by Reynolds and Smith, Stanton and Bairstow, and others, which appeared to require further examination.

The points referred to are, briefly stated, as follows :—

(1) The effect of the variation of tensile stress as distinguished from a variation of stress from tension to compression.
(2) The variation of the maximum limit when combined with a fixed lower limit of range of stress.
(3) The limiting range of stress and its relation to the maximum stress, its effect on the elastic properties of the material, and the connection between complete recovery and perfect elasticity.
(4) Any indications given by the crystalline structure as to whether failure is likely to occur.

The testing machine was specially designed for the setting up of tensile stresses only by the late Professor T. C. Fidler, M.I.C.E., and was constructed in the Engineering Department of University College, Dundee. The load is applied by means of hydraulic pressure acting on the underside of a piston to which is attached through a spherical bearing joint the upper end of the test piece, the lower end being similarly connected to a fixed cross-head. The number of alternations of pressure is capable of being varied from 10 to 18 per minute.

A special feature of the machine is its ability to take test pieces of the same dimensions as those ordinarily used in a Wicksted Machine with a length sufficiently great to allow of the use of a Ewing's Extensometer.

The material used in the first test pieces was Siemens Martin Steel, and under static load showed a yield stress of 15 tons per sq. in. and a maximum stress of 26·4 tons on the original section with an ultimate elongation of 32·8 per cent. on an 8-in. length. The later specimens, in order to fit in with the scheme of research framed by the Engineering Committee of the British Association on Complex Stresses, were of specially supplied Dead Mild Steel (·12 per cent. Carbon), yield stress 15·5 tons per sq. in., maximum stress 23·4 tons, and elongation 33·7 per cent.

In the series of tests, in which alternations of tensile stress only were given, it was found that :—

(1) After ordinary yield is exceeded and permanent elongation has taken place, the limits of the proportionality of stress and strain are raised. The extent of this elongation for any maximum stress depends on whether the stress has been applied in one stage or with a sufficient number of repetitions at each of several stages.
(2) The range of stress over which this proportionality is maintained is limited ; once established it is independent of the number of cyclical repetitions to which it is subjected.
(3) The range of stress may be again varied by further elongation, but to this there is a limit.
(4) Failure under repetitions of tensile stress occurs by the movement of the crystals relatively to one another, consequent on the existing range of stress being exceeded, or during the transition period when one range is being changed to another.
(5) Failure frequently originates by the range of stress, or even the maximum static stress of the material, being exceeded in parts of a section, and is due to mechanical flaws in the material or to non-axial loading.

The Strain-energy Function and the Elastic-limit.

By B. P. Haigh, *M.B.E., D.Sc.*

Introduction.

The elastic-limit of a ductile metal is usually defined as that limiting intensity of stress beyond which permanent strain is first produced ; or alternatively, beyond which stress and strain are no longer proportional. The same definition may be adopted for complex stresses, the intensities of all three principal stresses being then required to specify the elastic-limit.

Several hypotheses, based on direct experiment and empirical in nature, have been advanced with the object of establishing a direct relation between the elastic-limits for simple and complex stresses ; and certain of these are now in general use, yielding reliable results in particular circumstances. In what follows, reference will be made to three hypotheses—due to Lamé and Rankine, to de Saint Venant and to Tresca, Darwin, and Guest. According to different hypotheses, the maximum principal stress or strain, or the maximum tangential stress, or the latter together with internal friction, may be regarded as the criterion of elastic failure.

In studying these alternative hypotheses, it occurred to the author that a more general relation between the elastic-limits under simple and complex stresses might be found by directing attention to the *energy* absorbed by the material in virtue of its elastic strain. This view was based upon thermo-dynamic considerations ; but, in this paper, only the experimental aspect of the question will be discussed. On another occasion the author hopes to deal with the theoretical results obtained by applying the principles of thermodynamics to the current theory of ductile strain ; the process of strain being regarded as one in which crystalline metal is converted to the harder vitreous state in a manner that is thermodynamically reversible although associated (like every thermal process) with actions that are irreversible.

The mechanical energy absorbed by a body stressed within the elastic-range is variously termed the ' strain-energy ' or ' resilience.' The term ' limiting strain-energy ' will now be used to signify the quantities of energy that can be absorbed per unit volume of material uniformly strained to its elastic limit by the application of specified combinations of principal stresses. The immediate object of the investigation is to find how nearly constant is this quantity, for any one material, independently of the nature of the simple or complex stress applied. No new experiments will be quoted because the data available in published records afford ample scope for a preliminary investigation ; but it is hoped that the results may encourage other investigators to study the strain-energy function when analysing further experiments.

Strain-energy Functions.

The mean strain-energy of a test-piece, initially free from internal stress and then uniformly strained under complex stress, is readily expressed in terms of the three principal stresses, X, Y, and Z, and the elastic

constants of the material. Under a single principal stress, X, the strain energy depends only on Young's modulus E. Thus :

$$\text{Strain-energy} = W_x = \int_o^x X \frac{dx}{E} = X^2/2E$$

Similarly, under simple shear-stress Q with modulus of rigidity C; or under bulk-stress P with compressibility modulus K—the values are

$$W_q = Q^2/2\,C \text{ or } W_p = P^2/2\,K$$

Under two-dimensional stress, represented by two finite principal stresses X and Y, the elongation in the direction of either principal stress is the algebraic sum of two components produced by the two stresses, thus

$$e_x = (X - \sigma Y)/E$$

where σ is Poisson's ratio. Integrating the sum of the products $X.de_x$ and $Y.de_y$, to find the mean strain-energy W_{xy}, we have

$$2E.W_{xy} = (X^2 + Y^2 - 2\sigma.X.Y)$$

Taking $2E.W_{xy}$ as constant, this quadratic equation expresses the relation between two principal stresses varied in such a manner that the strain-energy W_{xy} is constant. This equation is plotted in fig. 16 for different

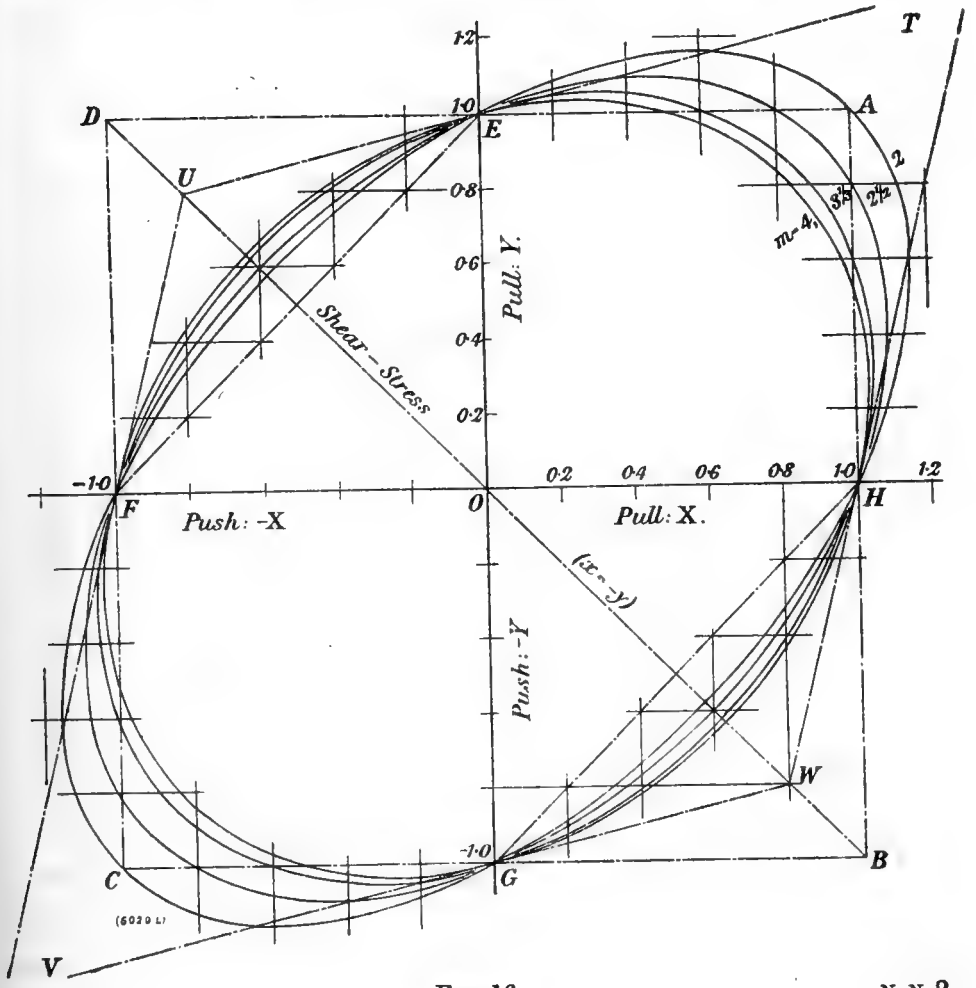

FIG. 16.

values of Poisson's ratio from 0.50″ to 0.25 ($m = 1/\sigma = 2, 2\frac{1}{2}, 3\frac{1}{3}$, and 4). The ellipses have been plotted to pass through the points ($X = \pm 1$, $Y = 0$ and $X = 0$, $Y = \pm 1$) representing the elastic-limits under simple longitudinal pull and pushes in different directions. The major and minor axes of the ellipses, at 45° to the axes of X and Y, are as given below :—

Value of m	2·0	2·5	3·0	$3\frac{1}{3}$	3·5	4·0
Semi-major axis	1·414	1·291	1·225	1·195	1·183	1·153
Semi-minor axis	0·817	0·845	0·867	0·879	0·882	0·895

On the hypothesis that the limiting strain-energy is constant and independent of the nature of the applied stress, these ellipses indicate the variations of the limiting principal stresses for the elastic-limit under two-dimensional stress. For example, the elastic-limit under simple shear-stress ($X = -Y$) should be somewhat more than half the tensile elastic-limit. Also, under combinations of similar principal stresses, *e.g.*, two pulls in perpendicular directions, the elastic-limit should be increased by the influence of the second stress when the latter is of moderate intensity ; and reduced when the two stresses approach equality. The square A, B, C, D, in the same diagram, represents Rankine's hypothesis that the elastic-limit depends solely on the principal stress—the limits under pull and push being here assumed to be equal. The six-sided figure A, H, G, C, F, E, A likewise represents Guest's law, that the elastic-limit is determined by the maximum tangential stress. Parallelograms, *e.g.*, T, W, V, U, represent de Saint Venant's hypothesis that elastic failure depends on the maximum principal strain. These latter parallelograms circumscribe the ellipses representing constant strain-energy, being tangent to the ellipses at the points E, F, G, H. It will be observed that this diagram affords a convenient means of comparing the results of experiment with the indications of the several hypotheses : sections of the diagram will be used for this purpose in subsequent figures.

For combinations of three finite principal stresses, the mean strain-energy may likewise be expressed,

$$2\mathrm{E}.\mathrm{W}_{xyz} = (\mathrm{X}^2 + \mathrm{Y}^2 + \mathrm{Z}^2) - 2\sigma.(\mathrm{Y}.\mathrm{Z} + \mathrm{Z}.\mathrm{X} + \mathrm{X}.\mathrm{Y})$$

Other forms of the energy function, based on the three principal stresses and two independent variables expressing the elasticity of isotropic materials, have been given by Lamé (1852) ; but the above is well known and, probably, the most convenient and fundamental.

For the more general case of non-isotropic crystals, Green (1837) established an expression in which 21 independent variables appear. It is important to observe that the simpler expressions are rigorously applicable only for isotropic materials ; and that, being applied to ordinary crystalline metal composed of large numbers of non-isotropic grains with axes oriented in different directions, they give only the mean strain-energy for the gross mass under uniformly applied stress. The quantities of energy absorbed by individual crystalline grains may vary above or below this mean value ; and may vary for different parts of individual grains according to the configuration of the boundaries. Evidence of this non-uniformity may be observed by studying the disposition of slip-bands within particular grains.

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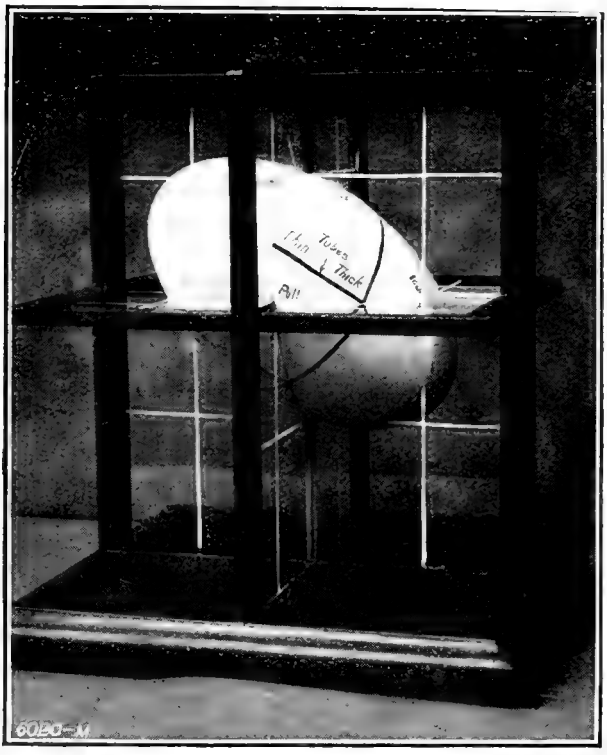

FIG. 17.

Illustrating the Report on Stress Distribution in Engineering Materials.

[*To face page* 489.

Instead of expressing the strain-energy in terms of the three mutually perpendicular principal stresses, we may adopt the method introduced by Kelvin, and express the state of stress in terms of a single bulk stress P and two mutually perpendicular shear stresses, Q_{xy} and Q_{zy}. The bulk stress is the algebraic mean of the three principal stresses,

$$P = \frac{1}{3}(X + Y + Z)$$

while the two shear-stresses are equal to the two smaller of the three residuals obtained by subtracting the bulk stress from the principals. For example, if the residual (Y — P) is numerically greater than (X — P) and (Z — P)—being equal and opposite to their sum (X + Z — 2P)—the two shear-stresses are

$$Q_{xy} = (X - P) = (2X/3 - Y/3 - Z/3)$$

and

$$Q_{zy} = (Z - P) = (2Z/3 - X/3 - Y/3).$$

In terms of these fundamental stresses, the mean strain-energy is simply the sum of the quantities due to the three independent stresses, viz. :—

$$W_{xyx} = (P^2/2K + Q^2{}_{xy}/2C + Q^2{}_{xy}/2C)$$

On substituting $K = E/3(1 - 2\sigma)$ and $C = E/2(1 + \sigma)$, and the values of the principal stresses, this expression naturally reduces to the form already quoted, giving the strain-energy in terms of X, Y, Z, E, and σ.

Figure 17 shows a model constructed to visualise the quadratic equation in the three stresses X, Y, and Z, every point on the surface having the same strain-energy. The symmetrical ellipsoid passes through the points $X = \pm 1$, $Y = Z = 0$, etc., representing the elastic-limits under simple pull and push in different directions and is oriented so that its major axis coincides with the line $X = Y = Z$. The form of the model varies for different values of Poisson's ratio, the ratios between the semi-major axis and the elastic-limit for simple pull or push being as given in the following table :—

Value of ratio semi-major axis to elastic-limit in tension	2·0	2·5	3·0	3⅓	3·5	4·0
	Infinity	2·235	1·732	1·582	1·528	1·414

The equal minor axes are identical with those of the ellipses shown in fig. 16 ; these being the traces of the model with the plane of projection, $Z = 0$. In the case of an incompressible substance (K = infinity, $m = 2{\cdot}0$) the model becomes a cylinder.

The lines drawn on the (glass) planes of projection represent the co-ordinates of the elastic-limits under simple pull and push. The markings on the surface of the ellipsoid represent particular combinations of stress, *e.g.*, the three-dimensional stresses in thick and thin tubes subjected to internal fluid-pressure. The circle drawn round the minor axis is the locus of points representing combinations of shear-stresses without bulk stress. Bulk stress alone is represented by the major axis, $X = Y = Z$.

Analysis of published experimental results.

The following diagrams represent a summary of the results of numerous determinations of the elastic-limits of different metals under two- and three-dimensional stresses. The diagrams for experiments with two-dimensional or nearly two-dimensional stresses have been drawn up on the following principle : The intensities of the principal stresses, under which permanent strain was observed, have been expressed as ratios to the single principal stress, which, acting alone as simple pull, produced permanent elongation. The values of these ratios, X and Y, have been taken as the co-ordinates of the points marked on the diagrams. Thus each point represents a comparison between two experiments, one under complex stress and the other under simple pull. The positions of the points record the stress-ratios only, not the absolute values of the stresses. When ascertainable, the elastic-limits of the test-pieces have been used as the basis of comparison, but in several instances the yield points have been compared in the same manner.

The diagrams also show the ellipses representing constant limiting strain-energy, and the figures corresponding to other hypotheses. The positions of the experimental points, relatively to these loci, afford a convenient and direct check on the validity of alternative hypotheses.

Figure 18 reproduces that part of the two-dimensional stress diagram which relates to pull, X, combined with a perpendicular pull or push, $\pm$Y. The majority of the experimental points represent Guest's experiments [4] on steel, brass, and copper tubes subjected to combinations of tension and torsion (quadrant XO = Y), or combinations of tension and internal pressure (quadrant XOY). In the latter experiments, the metal was subjected to three finite principal stresses ; but as the radial pressures that constitute the third stress are small in comparison with the tensions produced in thin-walled tubes, the third stress may be neglected ; or the points may be regarded as slightly in relief above the plane of the paper.

The values of m quoted for the steel tubes, deduced from determinations of E and C, vary between 2·36 and 3·50—a somewhat wide range ; but it is recognised that this method of measuring Poisson's ratio, although convenient and theoretically correct, is liable to give erroneous values when even small errors are present in the determination of the moduli. The values quoted for the brass and copper tubes are respectively 2·0 to 2·2 and 2·3. Ellipses have been plotted corresponding to $m = 2{\cdot}0$, 2·5, and $3\frac{1}{3}$.

Inspection of the diagram indicates that the points approximate to the ellipses, at least as closely as to any of the straight-line loci. The points lie outside the square HAEO where the two stresses are both pulls but the one substantially greater than the other ; and fall within the square near the corner A, where the stresses approach equality. And in the same quadrant XOY, the change from steel to brass or copper is accompanied by a general movement in the outward direction, as would be anticipated on the assumption that the limiting strain-energy is constant. In the lower quadrant, the points are widely distributed but generally

[4] J. J. Guest, *Phys. Society*, May 25, 1900.

lie between the lines representing constant maximum principal and tangential stresses, in the region occupied by the ellipses.

The thin steel tubes employed in Guest's experiments being of moderately high tensile material, with elastic-limits under simple tension from 15 to 27 tons per sq. in., it is inferred that the constant strain-energy hypothesis is reasonably applicable for ordinary steels although their microstructional features are too complex to admit of any complete theoretical treatment, such as would be required to apply thermodynamic principles.

Figure 18 shows, also, five experiments by Crawford[5] on flat steel plates

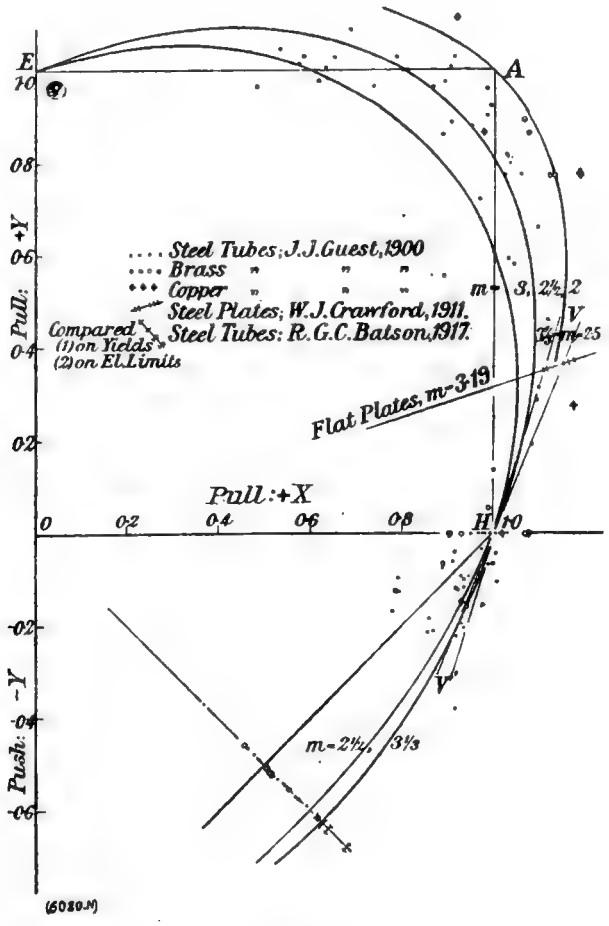

FIG. 18.

of circular profile, clamped at the edges and subjected to fluid pressure on one side. Crawford concludes that, for such plates, de Saint Venant's hypothesis (represented by the straight lines H V and H V′ for $m = 2{\cdot}5$ and $3\frac{1}{3}$) is more applicable than Rankine's hypothesis of constant maximum principal stress. The value of m for these plates, experimentally determined, was 3·19. As de Saint Venant's lines lie, in this part of the diagram,

[5] W. J. Crawford, *Proc. R.S.Edin.* (1911–12).

only slightly outside the ellipses which they touch at H, it follows that this and other evidence that supports de Saint Venant's hypothesis may be regarded as giving almost equal support to the hypothesis of constant strain-energy. When the two principal stresses are more nearly equal, as in rotating discs, de Saint Venant's hypothesis overestimates the elastic-limit and cannot be regarded as reliable.

Tests by Batson,[6] on two mild-steel tubes, are also represented in the same diagram. In these tubes, which were tested in torsion and in tension, the ratio between the elastic-limits is somewhat different from that between the yield-points. This may have been due to the comparatively thick walls of the tubes, the ratio between the internal and external diameters being 0·72. These results were described as supporting Guest's hypothesis, but are more closely in agreement with the hypothesis of constant limiting strain-energy.

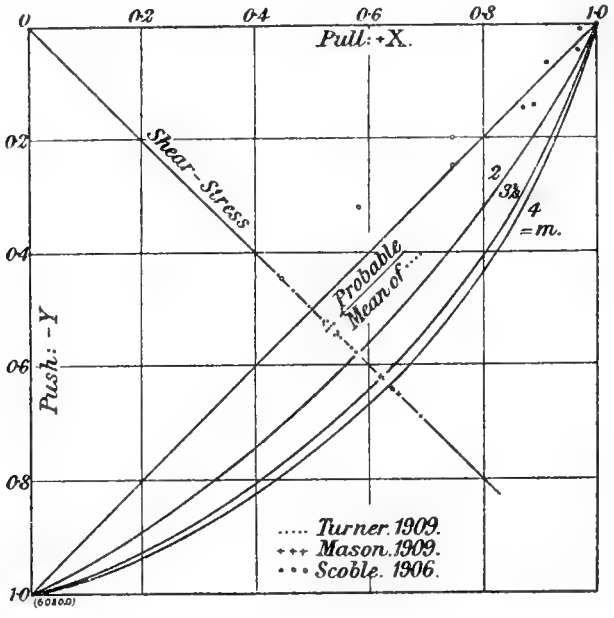

Fig. 19.

Figure 19 shows the portion of the diagram relating to combinations of pull and push; particularly with equal intensities, producing simple shear. Three experiments, described in detail by Mason,[7] are represented by points close to the ellipses; and a number of other experiments on steel tubes, more briefly mentioned in the same article, give points between the ellipses and the straight line HG. A number of points represent other experiments on steel tubes in torsion and pull, by Turner.[8] The ratio between the two elastic limits varies widely in the different specimens tested; but analysing the observations by the theory of probabilities—as applied in problems of external ballistics—Sears[9] showed that the

[6] R. G. C. Batson, *Proc. Inst.Mech.Eng.*, 1917.
[7] Wm. Mason, *Engineering*, December 24, 1909.
[8] Professor Turner, *Engineering*, February 1909.
[9] J. E. Sears, *Engineering*, February 19, 1909.

probable limit in torsion was $6\frac{1}{2}$ per cent. greater than half the elastic limit in tension. Several comparative tests by Scoble[10] are also represented in the same diagram. These were carried out on solid unannealed test-pieces subjected to combined bending and torsion, and the yield-points were quoted as the bases of comparison. The limits under combined stress appear unusually low in this series, lying well within the straight line HG.

Experiments with Combination of three Finite Principal Stresses.

For combinations of three finite principal stresses, the above method of comparison is less convenient than that adopted by Cook and Robertson[11] in their investigation of the elastic-limit of thick-walled tubes subjected to internal fluid-pressure. In this investigation, a number of tubes were tested under gradually increasing pressure, producing hoop-tension, axial-tension and radial pressure in the material of the inner layer. By varying the ratio, k, between the external and internal diameters of the tubes, the relative magnitudes of the three principal stresses were varied widely, affording a direct comparison of the effects of different complex stresses. The elastic-limit of the material under simple tension, F, was also measured and the limiting internal pressure, P, was expressed as a fraction of this. Since the lengths of the tubes were great enough to render the influence of the ends negligible, Lamé's method of calculating the principal stresses could be applied with confidence. These stresses are :

$$\begin{aligned} X &= \text{hoop tension} = P\,(k^2 + 1) \div (k^2 - 1) \\ Y &= \text{axial tension} = P \div (k^2 - 1) \\ Z &= \text{radial pressure} = P \end{aligned}$$

Cook and Robertson showed that, for each of the current hypotheses, the limiting internal pressure, P, could be expressed in terms of the elastic-limit, F ; thus :—

$$\begin{aligned} &\text{On Rankine's hypothesis } P/F = (k^2 - 1) \div (k^2 + 1) \\ &\text{On Guest's hypothesis } P/F = (k^2 - 1) \div 2k^2 \\ &\text{On de Saint Venant's (with } m = 4) \; P/F = 4\,(k^2 - 1) \div (5k^2 + 2). \end{aligned}$$

Figure 20 shows these expressions plotted, as functions of k, for tubes of different thicknesses. Cook and Robertson's experimental values are also plotted and lie well below graphs I and II, representing the Rankine and St. Venant hypotheses, but above the third graph, III, which represents Guest's hypothesis of constant maximum tangential-stress. The author has added two graphs, IV, giving the values of the ratio, P/F, corresponding to the hypothesis of constant strain-energy ; and it is observed that these follow the experimental points very closely.

According to the hypothesis of constant strain-energy the relation

[10] W. A. Scoble, *Phil. Mag.* ii. 1906.
[11] Cook and Robertson, *Engineering*, December 15, 1911.

between P/F and k is deduced in the following manner, which may be regarded as typical of the methods applicable wherever the ratios between the principal stresses are known. In the general equation for strain-energy

$$W_{xyz}=\frac{1}{2E}(X^2+Y^2+Z^2)-\frac{1}{ME}(YZ+XZ+ZX)$$

substitute the expressions for the principal stresses,

$$W_{xyz}=\frac{P^2}{E(k^2-1)}\ 2\times\left\{\tfrac{1}{2}\left[(k^2-1)^2+(k^2+1)^2+1\right]\right.$$

$$\left.-\frac{1}{m}\left[-(k^2-1)-(k^2+1)(k^2-1)+(k^2+1)\right]\right\}$$

$$=\frac{P^2}{2E(k^2-1)^2}\left[3\left(1-\frac{2}{m}\right)+2k^4\left(1+\frac{1}{m}\right)\right]=\frac{P^2}{2(k^2-1)^2}\left[\frac{1}{K}+\frac{k^4}{C}\right].$$

Equating this quantity to the strain-energy in simple tension, $W_f=F^2/2E$, we have

$$\frac{P^2}{F^2}=\frac{(k^2-1)^2}{3(1-2\sigma)+2k^4(1+\sigma)}$$

whence, substituting $m=1/\sigma=4$, we have

$$\frac{P}{F}=\frac{2(k^2-1)}{\sqrt{6+10k^4}}$$

which expression gives one of the two graphs, IV, plotted in the diagram.

The validity of the constant limiting strain-energy hypothesis, as a

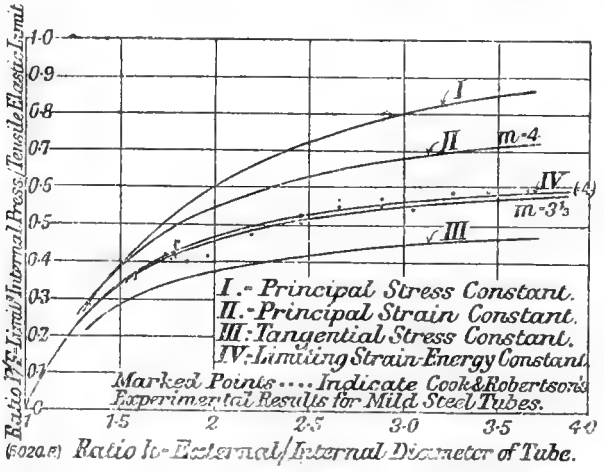

FIG. 20.

serviceable approximation to a law that is doubtless more complex, may be inferred not only from scientific investigation of cases, such as the above, that admit of exact calculation and measurement, but also from

observation of phenomena that do not admit of exact treatment. The process of wire-drawing is a case in point. In drawing, wire is subjected to three dimensional stresses in the dies, viz., axial tension and two-dimensional compression—a combination which, in the model shown in fig. 20, is represented by the region at the rear of the upper right-hand quadrant, where the (vertical) tension is comparatively low. Approximate calculations, based on the hypothesis of constant limiting strain-energy, indicate that the pull required to give $7\frac{1}{2}$ per cent. reduction in dies of ordinary proportions should vary from 30 to 50 per cent. of the tensile strength; whereas, in practice, it is found that the actual pull required seldom reaches half the tensile strength. Although the influence of friction is too uncertain to admit of accurate calculation, the agreement is, at least, within the limits of uncertainty.

It may be noted, also, that strain-energy limits are already used in practice, to a limited extent, in connection with calculations relating to springs. The energy that can be stored per unit volume of solid round wire, wound free in a closely-coiled helical spring, with maximum shear-stress q is $W = (\frac{1}{4}q^2/C)$, where C is the modulus of rigidity. As q varies from about 40 to 80,000 lbs. per sq. in. and C is approximately 12,000,000, W runs from 330 to 1,300 inch-lbs. per cubic inch. In a spring required to carry a concentrated load P with an elastic deflection δ, the total stored-energy is $(\frac{1}{2}P\ \theta)$; hence the volume of metal required is simply $(\frac{1}{2}P\ \theta \div W)$. The hypothesis that the limiting strain-energy per unit volume is the same, in torsion and bending, leads to the conclusion that the helical spring should be capable of storing 50 per cent. more energy than a well-designed coach-spring of equal volume (with constant maximum stress along its many leaves); the expressions for the mean strain-energy being respectively $(\frac{1}{4}q^2/C)$ and $(\frac{1}{6}f^2/E)$, which are in the ratio 6 : 4. It may be observed that this conclusion is roughly endorsed by experience of the endurance of such springs under comparable conditions of service.

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FOR THE ADVANCEMENT OF SCIENCE

1919-20

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NATURAL HISTORY

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AND

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CORRECTED TO MAY 1, 1920

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1919–20.

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Names of Members whose addresses are incomplete or not known are in *italics*.

Notice of changes of residence should be sent to the Assistant Secretary, Burlington House, London, W. 1.

Year of Election.

1905. *à-Ababrelton, Robert, F.R.G.S., F.S.S. P.O. Box 322, Pietermaritzburg, Natal. Care of Royal Colonial Institute, Northumberland-avenue, W.C. 2.
1919. §Abbott, A. J. 23 Westby-road, Bournemouth.
1914. ‡Abbott, Hon. R. H. S. Rowan-street, Bendigo, Victoria.
1881. *Abbott, R. T. G. Whitley House, Malton.
1885. *ABERDEEN, The Marquis of, G.C.M.G., LL.D. Haddo House, Aberdeen.
1885. ‡Aberdeen, The Marchioness of. Haddo House, Aberdeen.
1873. *ABNEY, Captain Sir W. DE W., K.C.B., D.C.L., F.R.S., F.R.A.S. (Pres. A, 1889; Pres. L, 1903; Council, 1884–89, 1902–05, 1906–12.) Measham Hall, Leicestershire.
1877. *Acland, Captain Francis E. Dyke, R.A. Walwood, Banstead, Surrey.
1894. *ACLAND, HENRY DYKE, F.G.S., F.S.A. Chy-an-Mor, Gyllyngvase, Falmouth.
1877. *Acland, Theodore Dyke, M.D. 19 Bryanston-square, W. 1.
1904. ‡Acton, T. A. 41 Regent-street, Wrexham.
1898. ‡ACWORTH, W. M., M.A. (Pres. F, 1908.) The Albany, W. 1.
1915. ‡Adam, Sir Frank Forbes, C.I.E., LL.D. Hankelow Court, Audlem.

Year of Election.

1887. ‡ADAMI, J. G., M.A., M.D., F.R.S., Professor of Pathology in McGill University, Montreal, Canada.
1901 §ADAMS, JOHN, M.A., B.Sc., LL.D. (Pres. L, 1912), Professor of Education in the University of London. 23 Tanza-road, Hampstead, N.W. 3.
1908. *Adamson, R. Stephen. The University, Manchester.
1913. ‡Addison, W. H. F. Medical School, The University of Pennsylvania.
1890. ‡ADENEY, W. E., D.Sc., F.C.S. Burnham, Monkstown, Co. Dublin.
1899. *Adie, R. H., M.A., B.Sc. 136 Huntingdon-road, Cambridge.
1908. §Adkin, Robert. Hodeslea, Meads, Eastbourne.
1912. ‡Afanassieff, Apollo. Physical Institute, Imperial University, Petrograd.
1908. *Agar, W. E., M.A. Natural History Department, The University, Glasgow.
1902. ‡Agnew, Samuel, M.D. Bengal-place, Lurgan.
1871. *Ainsworth, Sir John Stirling, Bart., M.P. Harecroft, Gosforth, Cumberland.
1909. *AIRD, Sir JOHN. Canadian Bank of Commerce, Toronto, Canada.
1914. ‡Airey, J. W. Barooma, Vernon-street, Strathfield, Sydney.
1911. §Airey, John R., M.A., D.Sc. The Training College, Beckett's Park, Leeds.
1895. **Airy, Hubert, M.D. Stoke House, Woodbridge, Suffolk.*
1901. ‡Aitken, Thomas, M.Inst.C.E. County Buildings, Cupar-Fife.
1884. *Alabaster, H. Milton, Grange-road, Sutton, Surrey.
1905. ‡Albright, Miss. Finstal Farm, Finstal, Bromsgrove, Worcestershire.
1886. *Albright, G. S., C.B.E. Broomsberrow Place, Ledbury.
1913. ‡Albright, W. A. 29 Frederick-road, Edgbaston, Birmingham.
1900. *Aldren, Francis J., M.A. The Lizans, Malvern Link.
1896. §Aldridge, J. G. W., Assoc.M.Inst.C.E. 39 Victoria-street, Westminster, S.W. 1.
1905 *Alexander, J. Abercromby, F.R.G.S. Waverley, Rossmore-avenue, Parkstone, Dorset.
1888. *Alexander, Patrick Y. 3 Whitehall-court, S.W. 1.
1910. *Alexander, W. B., B.A. Western Australian Museum, Perth, West Australia. Temp. Undercroft, Reigate.
1898. *Alford, Mrs. Gertrude. Tréhill, 294 Edward-road, Edgbaston, Birmingham.
1883. ‡Alger, W. H. The Manor House, Stoke Damerel, South Devon.
1883. ‡Alger, Mrs. W. H. The Manor House, Stoke Damerel, South Devon.
1914. ‡Allan, Edward F., B.A. 37 Wattletree-road, Malvern, Victoria.
1901. *Allan, James A. 21 Bothwell-street, Glasgow.
1904. *Allcock, William Burt. Emmanuel College, Cambridge.
1879. *Allen, Rev. A. J. C. 34 Lensfield-road, Cambridge.
1898. §ALLEN, E. J., D.Sc., F.R.S. The Laboratory, Citadel Hill, Plymouth.
1891. ‡Allen, H. A., F.G.S. 28 Jermyn-street, S.W. 1.
1915. *ALLEN, J. E. 6 Market-square, Saffron Walden, Essex.
1919. §Allen, W. H. Bromham House, Bromham, near Bedford.
1907. *Allorge, M. M., L. ès Sc., F.G.S. Villa St. Germain, Louviers, France.
1912. *Allworthy, S. W., M.A., M.D. The Manor House, Antrim-road, Belfast.
1887. ‡Alward, G. L. Enfield Villa, Waltham, Grimsby, Yorkshire.
1915. ‡*Ambler, Clement.* 34 *Seymour-grove, Old Trafford.*
1883. ‡Amery, John Sparke. Druid, Ashburton, Devon.

Year of Election.

1909. ‡Ami, H. M., M.D. Ottawa, Canada.
1884. ‡Ami, Henry, M.A., D.Sc., F.G.S. Geological Survey, Ottawa, Canada.
1914. ‡Anderson, Miss Adelaide M. Home Office, S.W. 1.
1910. ‡Anderson, Alexander. Tower House, Dore, near Sheffield.
1905. *Anderson, C. L. P.O. Box 2162, Johannesburg.
1908. ‡Anderson, Edgar. Glenavon, Merrion-road, Dublin.
1885. *Anderson, Hugh Kerr, M.A., M.D., F.R.S. Caius College, Cambridge.
1914. ‡Anderson, J. R. V. School of Mines, Bendigo, Victoria.
1901. *Anderson, James. 166 Buchanan-street, Glasgow.
1899. *Anderson, Miss Mary Kerr. 13 Napier-road, Edinburgh.
1888. *Anderson, R. Bruce. 5 Victoria-street, S.W. 1.
1914. ‡Anderson, Valentine G. 31 Victoria-avenue, Canterbury, Victoria, Australia.
1901. *Anderson, Dr. W. Carrick. 7 Scott-street, Garnethill, Glasgow.
1908. ‡Anderson, William. Glenavon, Merrion-road, Dublin.
1911. *Andrade, E. N. da C. 18 Keyes-road, Cricklewood, N.W. 2.
1907. ‡*Andrews, A. W. Adela-avenue, West Barnes-lane, New Malden, Surrey.*
1909. ‡Andrews, Alfred J. Care of Messrs. Andrews, Andrews, & Co., Winnipeg, Canada.
1895. ‡Andrews, Charles W., B.A., D.Sc., F.R.S. British Museum (Natural History), S.W. 7.
1914. ‡Andrews, E. C., B.A., F.G.S. Geological Branch, Department of Mines, Sydney, N.S.W.
1909. ‡Andrews, G. W. 433 Main-street, Winnipeg, Canada.
1912. §Angus, Miss Mary. 354 Blackness-road, Dundee.
1886. ‡Ansell, Joseph. 27 Bennett's-hill, Birmingham.
1917. *Anthony, Charles, F.R.S.E., M.Inst.C.E. Vieytes Gorriti, Bahia Blanca, Argentine.
1919. §Anthony, Harvey Mitchell, Director of Vocational Education. Muncie, Indiana, U.S.A.
1901. ‡Arakawa, Minozi. Japanese Consulate, 1 Broad Street-place, E.C. 2.
1904. *Arber, Mrs. E. A. Newell, D.Sc., F.L.S. 52 Huntingdon-road, Cambridge.
1913. ‡Archer, J. Hillside, Crowcombe, West Somerset.
1913. *Archer, R. L., M.A., Professor of Education in University College, Bangor. Plas Menai, Bangor.
1894. ‡Archibald, A. Holmer, Court-road, Tunbridge Wells.
1909. ‡Archibald, Professor E. H. Chemistry Department, University of British Columbia, Vancouver, B.C., Canada.
1909. ‡Archibald, H. Care of Messrs. Machray, Sharpe, & Dennistoun, Bank of Ottawa Chambers, Winnipeg, Canada.
1883. *Armistead, William. Hillcrest, Oaken, Wolverhampton.
1908. ‡Armstrong, E. C. R., M.R.I.A., F.R.G.S. 73 Park-avenue, Sydney-parade, Dublin.
1903. *Armstrong, E. Frankland, D.Sc., Ph.D. (Council, 1917– .) Greenbank, Greenbank-road, Latchford, Warrington.
1873. *Armstrong, Henry E., Ph.D., LL.D., F.R.S. (Pres. B, 1885, 1909; Pres. L, 1902; Council, 1899–1905, 1909–16.) 55 Granville-park, Lewisham, S.E. 13.
1909. ‡Armstrong, Hon. Hugh. Parliament Buildings, Kennedy-street, Winnipeg, Canada.
1905. ‡Armstrong, John. Kamfersdam Mine, near Kimberley, Cape Colony.

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1915. ‡Arnold, J. O., F.R.S., East Grove House, Broomsgrove-road, Sheffield.
1915. ‡Arnold-Bernard Pierre. 662 West End-avenue, New York City, U.S.A.
1904. ‡Arunachalam, P. Ceylon Civil Service, Colombo, Ceylon.
1870. *Ash, Dr. T. Linnington. Penroses, Holsworthy, North Devon.
1903. *Ashby, Thomas, M.A., D.Litt. The British School, Rome.
1909. ‡Ashdown, J. H. 337 Broadway, Winnipeg, Canada.
1916. ‡Ashley, Miss Anne, M.A. 3 Yateley-road, Edgbaston, Birmingham.
1907. ‡Ashley, Sir W. J., M.A. (Pres. F, 1907), Professor of Commerce in the University of Birmingham. 3 Yateley-road, Edgbaston, Birmingham.
1919. §Ashling, Herbert. (Local Sec. 1919.) Municipal Offices, Bournemouth.
1915. *Ashton, Miss Margaret. 8 Kinnaird-road, Withington, Manchester.
1920. M Ashton, Percival John. 83 Avenue-chambers, W.C. 1.
1915. ‡Ashworth, Arthur. Ellerslie, Walmersley-road, Bury.
1903. *Ashworth, J. H., D.Sc., F.R.S., Professor of Zoology in the University of Edinburgh. 69 Braid-avenue, Edinburgh.
1914. *Ashworth, Mrs. J. H. 69 Braid-avenue, Edinburgh.
1890. ‡Ashworth, J. Reginald, D.Sc. 55 King-street South, Rochdale.
1915. ‡Ashworth, John. 77 King-street, Manchester.
1916. *Ashworth, John H. The Bungalow, 151 St. Andrew's-road South, St. Anne's-on-Sea.
1875. *Aspland, W. Gaskell. Nyali Sisal Estates, Mombasa, East Africa.
1905. ‡Assheton, Mrs. Grantchester, Cambridge.
1908. §Astley, Rev. H. J. Dukinfield, M.A., Litt.D. East Rudham Vicarage, King's Lynn.
1919. §Atkins, William. 40 Wimborne-road, Bournemouth.
1898. *Atkinson, E. Cuthbert. 5 Pembroke-vale, Clifton, Bristol.
1894. *Atkinson, Harold W., M.A. West View, Eastbury-avenue, Northwood, Middlesex.
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1881. ‡Atkinson, Robert William, F.C.S., F.I.C. (Local Sec. 1891.) 10 North Church-street, Cardiff.
1919. §Atkinson, William. 142 Tweedale-street, Rochdale.
1906. ‡Auden, G. A., M.A., M.D. 42 Lordswood-road, Harborne, Birmingham.
1907. §Auden, H. A., D.Sc. 52 Calthorpe-street, Garston, Liverpool.
1912. *Austin, Percy C., M.A., D.Sc. Heathside, 17 Talbot Hill-road, Winton, Bournemouth.
1914. ‡Avery, D., M.Sc. Collins House, Collins-street, Melbourne.
1909. ‡Axtell, S. W. Stobart Block, Winnipeg, Canada.

1914. ‡Baber, Z., Professor of Geography and Geology in the University of Chicago, U.S.A.
1883. *Bach-Gladstone, Madame Henri. 147 Rue de Grenelle, Paris.
1919. *Bacon, Professor Frederic, M.A., M.I.M.E. University College, Cardiff.
1887. *Bacon, Thomas Walter. Ramsden Hall, Billericay, Essex.
1903. ‡*Baden-Powell, Major B.* 32 *Prince's-gate, S.W.* 7.
1907. §Badgley, Colonel W. F., Assoc.Inst.C.E., F.R.G.S. Verecroft, Devizes.

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1914. ‡Bage, Charles, M.A., M.D. 139 Collins-street, Melbourne.
1914. ‡Bage, Miss Freda. Women's College, Brisbane, Australia.
1908. *Bagnall, Richard Siddoway, F.L.S. Penshaw Lodge, Penshaw, Co. Durham.
1905. ‡Baikie, Robert. P.O. Box 36, Pretoria, South Africa.
1883. ‡Baildon, Dr. 42 Hoghton-street, Southport.
1883. *Bailey, Charles, M.Sc., F.L.S. Haymesgarth, Cleeve Hill S.O., Gloucestershire.
1887. *Bailey, G. H., D.Sc., Ph.D. Edenmor, Kinlochleven, Argyll, N.B.
1905. *Bailey, Harry Percy. Montrose, Northdown, Margate.
1914. ‡Bailey, P. G. 4 Richmond-road, Cambridge.
1905. ‡Bailey, Right Hon. W. F., C.B. Land Commission, Dublin.
1894. *Baily, Francis Gibson, M.A. Newbury, Colinton, Midlothian.
1878. ‡Baily, Walter. 4 Rosslyn-hill, Hampstead, N.W. 3.
1914. ‡Bainbridge, F. A., M.D., F.R.S., Professor of Physiology in the University of Durham, Newcastle-on-Tyne.
1919. §Bairstow, Leonard, C.B.E., F.R.S., 63 Holmesdale-road, Hampton Wick.
1905. *Baker, Sir Augustine. 56 Merrion-square, Dublin.
1913. *Baker, Bevan B., B.Sc. Frontenac, Donnington-road, Harlesden, N.W. 10.
1910. ‡Baker, H. F., Sc.D., F.R.S. (Pres. A, 1913), Lowndean Professor of Astronomy and Geometry in the University of Cambridge. St. John's College, Cambridge.
1886. ‡Baker, Harry, F.I.C. Beacon Field, Weston-road, Runcorn.
1914. ‡Baker, R. T. Technological Museum, Sydney, N.S.W.
1907. ‡Baldwin, Walter. 382 Brunshaw Top, Burnley.
1904. ‡Balfour, The Right Hon. A. J., O.M., D.C.L., LL.D., M.P. F.R.S., Chancellor of the University of Edinburgh. (President, 1904.) Whittingehame, Prestonkirk, N.B.
1894. ‡Balfour, Henry, M.A. (Pres. H, 1904.) Langley Lodge, Headington Hill, Oxford.
1905. ‡Balfour, Mrs. H. Langley Lodge, Headington Hill, Oxford.
1875. ‡Balfour, Sir Isaac Bayley, K.B.E., M.A., D.Sc., M.D., F.R.S., F.R.S.E. F.L.S. (Pres. D, 1894; Pres. K, 1901), Professor of Botany in the University of Edinburgh. Inverleith House, Edinburgh.
1838. ‡Balfour, Lady I. Bayley. Inverleith House, Edinburgh.
1905. ‡Balfour, Mrs. J. Dawyck, Stobo, N.B.
1905. ‡*Balfour, Lewis.* 11 *Norham-gardens, Oxford.*
1905. ‡Balfour, Miss Vera B. Dawyck, Stobo, N.B.
1908. ‡*Ball, T. Elrington.* 6 *Wilton-place, Dublin.*
1883. *Ball, W. W. Rouse, M.A. Trinity College, Cambridge.
1920. MR Ballard, P. B., M.A., D.Lit. 148 Sutton Court-road, Chiswick, W. 4.
1914. ‡Balsillie, J. Greene. P.M.G.'s Department, Melbourne.
1917. ‡Baly, E. C. C., C.B.E., M.Sc., F.R.S., Professor of Inorganic Chemistry in the University of Liverpool.
1909. ‡Bampfield, Mrs. E. 309 Donald-street, Winnipeg, Canada.
1912. *Bancroft, Miss Helen, D.Sc., F.L.S. 260 Normanton-road, Derby.
1898. ‡Bannerman, W. Bruce, F.S.A. 4 The Waldrons, Croydon.
1890. *Barber-Starkey, W. J. S. Aldenham Park, Bridgnorth, Salop.
1915. ‡Barclay, R. Noton. 35 Whitworth-street West, Manchester.
1860. *Barclay, Robert. High Leigh, Hoddesdon, Herts.
1902. ‡Barcroft, H., D.L. The Glen, Newry, Co. Down.
1902. ‡Barcroft, Joseph, M.A., B.Sc., F.R.S. King's College, Cambridge.

Year of Election.

1911. ‡Barger, George, M.A., D.Sc., F.R.S., Professor of Chemistry in the Royal Holloway College. Malahide, Englefield Green, Surrey.
1904. §Barker, B. T. P., M.A., Professor of Agricultural Biology in the University of Bristol. Fenswood, Long Ashton, Bristol.
1906. *Barker, Geoffrey Palgrave. Henstead Hall, Wrentham, Suffolk.
1899. ‡Barker, John H., M.Inst.C.E. Brackendale, Farquhar-road, Edgbaston, Birmingham.
1882. *Barker, Miss J. M. Sunny Bank, Scalby, Scarborough.
1910. *Barker, Raymond Inglis Palgrave. Henstead Hall, Wrentham, Suffolk.
1913. ‡Barling, Dr. Gilbert, C.B. Blythe Court, Norfolk-road, Edgbaston, Birmingham.
1909. ‡Barlow, Lieut.-Colonel G. N. H. Care of Messrs. Cox & Co., 16 Charing Cross, S.W. 1.
1889. ‡Barlow, H. W. L., M.A., M.B., F.C.S. The Park Hospital, Hither Green, S.E.
1885. *Barlow, William, F.R.S., F.G.S. The Red House, Great Stanmore.
1881. *Barnard, William, LL.B. 3 New-court, Lincoln's Inn, W.C. 2.
1904. ‡Barnes, Rev. E. W., M.A., Sc.D., F.R.S. The Temple, E.C. 4.
1907. ‡Barnes, Professor H. T., Sc.D., F.R.S. McGill University, Montreal, Canada.
1915. §Barnes, Jonathan. 301 Great Clowes-street, Higher Broughton, Manchester.
1909. *Barnett, Miss Edith A. Holm Leas, Worthing.
1913. §Barnett, Thomas G. The Hollies, Upper Clifton-road, Sutton Coldfield.
1881. ‡Barr, Archibald, D.Sc., M.Inst.C.E. (Pres. G, 1912.) Caxton-street, Anniesland, Glasgow.
1904. ‡Barrett, Arthur. 6 Mortimer-road, Cambridge.
1872. *Barrett, Sir W. F., F.R.S., F.R.S.E., M.R.I.A. 31 Devonshire-place, W. 1.
1874. *Barrington-Ward, Rev. Mark J., M.A., F.L.S., F.R.G.S. The Rectory, Duloe S.O., Cornwall.
1893. *Barrow, George, F.G.S. 202 Brecknock-road, Tufnell Park, N. 19.
1913. ‡Barrow, Harrison. 57 Wellington-street, Edgbaston, Birmingham.
1913. ‡Barrow, Louis. 155 Middleton Hall-road, King's Norton.
1913. ‡Barrow, Walter. 13 Ampton-road, Edgbaston, Birmingham.
1908. ‡Barry, Gerald H. Wiglin Glebe, Carlow, Ireland.
1884. *Barstow, Miss Frances A. Garrow Hill, near York.
1890. *Barstow, J. J. Jackson. The Lodge, Weston-super-Mare.
1890. *Barstow, Mrs. The Lodge, Weston-super-Mare.
1909. ‡Bartleet, Arthur M. 138 Hagley-road, Edgbaston, Birmingham.
1909. ‡Bartlett, C. Bank of Hamilton-building, Winnipeg, Canada.
1919. §Bartlett, F. C. St. John's College, Cambridge.
1914. ‡Barton, E. C. City Electric Light Company, Brisbane, Australia.
1893. *Barton, Edwin H., D.Sc., F.R.S., F.R.S.E., Professor of Experimental Physics in University College, Nottingham.
1908. ‡Barton, Rev. Walter John, M.A., F.R.G.S. Epsom College, Surrey.
1904. *Bartrum, C. O., B.Sc. 32 Willoughby-road, Hampstead, N.W. 3
1888. *Basset, A. B., M.A., F.R.S. Fledborough Hall, Holyport, Berkshire.
1891. ‡Bassett, A. B. Cheverell, Llandaff.
1866. *Bassett, Henry. 26 Belitha-villas, Barnsbury, N. 1.

Year of Election.

1911. *Bassett, Henry, jun., D.Sc., Ph.D. University College, Reading
1889. ‡Bastable, Professor C. F., M.A., F.S.S. (Pres. F, 1894.) 52 Brighton-road, Rathgar, Co. Dublin.
1912. ‡Bastian, Staff-Surgeon William, R.N. Chesham Bois, Buckinghamshire.
1883. ‡Bateman, Sir A. E., K.C.M.G. Woodhouse, Wimbledon Park, S.W.
1905. *Bateman, Mrs. F. D. The Rectory, Minchinhampton.
1907. *Bateman, Harry. Thorp College of Technology, Pasadena, California, U.S.A.
1914. ‡Bates, Mrs. Daisy M. 210 Punt-road, Prahran, Victoria.
1884. ‡Bateson, Professor William, M.A., F.R.S. (President, 1914; Pres. D, 1904.) The Manor House, Merton, S.W. 19.
1914. ‡Bateson, Mrs. The Manor House, Merton, S.W. 19.
1881. *Bather, Francis Arthur, M.A., D.Sc., F.R.S., F.G.S. British Museum (Natural History), S.W. 7.
1915. ‡Batho, Cyril, Professor of Applied Mechanics in McGill University, Montreal.
1906. ‡Batty, Mrs. Braithwaite. Ye Gabled House, The Parks, Oxford.
1904. ‡Baugh, J. H. Agar. 92 Hatton-garden, E.C. 1.
1909. ‡Bawlf, Nicholas. Assiniboine-avenue, Winnipeg, Canada.
1913. §Bawtree, A. E., F.R.P.S. Lynton, Manor Park-road, Sutton, Surrey.
1912. *Baxter, Miss Evelyn V. Roselea, Kirkton of Largo, Fife.
1912. *Bayliss, W. M., M.A., D.Sc., F.R.S. (Pres. I, 1915), Professor of General Physiology in University College, London, W.C. 1.
1914. ‡Bayly, P. G. W. Mines Department, Melbourne.
1876. *Baynes, Robert E., M.A. Christ Church, Oxford.
1887. *Baynes, Mrs. R. E 2 Norham-gardens, Oxford.
1914. ‡Beach, Henry, J.P. Clonesslea, Herbert-street, Dulwich Hill, Sydney.
1919. **Beadnell, H. J. Llewellyn, F.G.S. Hafod, Llandinam, Montgomeryshire.*
1905. ‡Beare, Miss Margaret Pierrepont. 10 Regent-terrace, Edinburgh.
1889. §Beare, Professor T. Hudson, B.Sc., F.R.S.E., M.Inst.C.E. The University, Edinburgh.
1905. ‡Beare, Mrs. T. Hudson. 10 Regent-terrace, Edinburgh.
1905. ‡Beattie, Professor J. C., D.Sc., F.R.S.E. South African College, Cape Town.
1916. *Beatty, Richard T., M.A., D.Sc. Physics Laboratory, Queen's University, Belfast.
1900. ‡Beaumont, Professor Roberts. M.I.Mech.E. The University, Leeds.
1885. *Beaumont, W. W., M.Inst.C.E. Outer Temple, 222 Strand, W.C. 2.
1914. ‡Beaven, E. S. Eastney, Warminster.
1887. *Beckett, John Hampden. Corbar Hall, Buxton, Derbyshire.
1904. §Beckit, H. O. Cheney Cottage, Headington, Oxford.
1885. ‡Beddard, Frank E., M.A., D.Sc., F.R.S., F.Z.S., Prosector of the Zoological Society of London, Regent's Park, N.W. 1.
1911. ‡*Beddow, Fred, D.Sc., Ph.D.* 2 *Pier-mansions, Southsea.*
1915. §Bedford, Fred, Ph.D., B.Sc. Dovercourt, Heslington-lane, York.
1904. *Bedford, T. G., M.A. 13 Warkworth-street, Cambridge.
1891. ‡Bedlington, Richard. Gadlys House, Aberdare.
1878 §Bedson, P. Phillips, D.Sc., F.C.S. (Pres. B. 1919; Local Sec. 1889, 1916), Professor of Chemistry in Armstrong College, Newcastle-upon-Tyne.
1901. *Beilby, Sir G. T., LL.D., F.R.S. (Pres. B, 1905.) 11 University-gardens, Glasgow.

Year of Election.

1905. ‡Beilby, Hubert. 11 University-gardens, Glasgow.
1914. §Belas, Philip E., B.A. University College, Cork.
1891. *Belinfante, L. L., M.Sc., Assist. Sec. G.S. Burlington House, W. 1.
1916. ‡Bell, Alfred Ernest. Low Gosforth House, Gosforth.
1909. ‡Bell, C. N. (Local Sec. 1909.) 121 Carlton-street, Winnipeg, Canada.
1894. ‡Bell, F. Jeffrey, M.A., F.Z.S. Athenæum Club, Pall Mall, S.W. 1.
1883. *Bell, John Henry. 102 Leyland-road, Southport.
1919. *Bell, Sir Hugh, Bart., C.B., D.L., J.P. (Pres. F. 1919.) Rounton Grange, Northallerton.
1915. §Bell, S. B. Carrara House, Lytham-road, Ashton-on-Ribble, Preston.
1888. *Bell, Walter George, M.A. Trinity Hall, Cambridge.
1914. ‡Bell, William Reid, M.Inst.C.E. Burnie, Tasmania.
1919. *Bellamy, Miss E. F. University Observatory, Oxford.
1908 *Bellamy, Frank Arthur, M.A., F.R.A.S. University Observatory, Oxford.
1904. ‡Bellars, A. E. Magdalene College, Cambridge.
1913. *Belliss, John, M.I.M.E. Darlinghurst, Carpenter-road, Edgbaston, Birmingham.
1893. *Bemrose, H. H., Sc.D., F.G.S. Ash Tree House, Osmaston-road, Derby.
1916. §Bennett, Arthur, J.P. Market-gate Chambers, Warrington.
1901. ‡Bennett, Professor Peter. 207 Bath-street, Glasgow.
1909. *Bennett, R. B., K.C. Calgary, Alberta, Canada.
1909. ‡Benson, Miss C. C. Terralta, Port Hope, Ontario, Canada.
1903. §Benson, D. E. Queenwood, 12 Irton-road, Southport.
1901. *Benson, Miss Margaret J., D.Sc. Royal Holloway College, Englefield Green.
1914. ‡Benson, W. Killara, Sydney, N.S.W.
1887. *Benson, Mrs. W. J. 5 Wellington-court, Knightsbridge, S.W. 1.
1898. *Bent, Mrs. Theodore. 13 Great Cumberland-place, W. 1.
1904. ‡Bentley, B. H., M.A., Professor of Botany in the University of Sheffield.
1905. *Bentley, Wilfred. Inglewood, Edgerton, Huddersfield.
1919. §Berg, Count Frederick. 18 Florence-road, Boscombe.
1896. *Bergin, William, M.A., Professor of Natural Philosophy in University College, Cork.
1919. §Beringer, Dr. J. Care of Sidney Chambers, Esq., 25 Waldegrave-road, S.E. 19.
1894. §Berkeley, The Earl of, F.R.S., F.C.S. (Council, 1909–10.) Foxcombe, Boarshill, near Abingdon.
1905. *Bernacchi, Lieut.-Com., L. C., O.B.E., F.R.G.S. 54 Inverness-terrace, W. 2.
1906. *Bernays, Albert Evan. 3 Priory-road, Kew, Surrey.
1894. *Berridge, Douglas, M.A., F.C.S. The College, Malvern.
1908. *Berridge, Miss Emily M. Dunton Lodge, The Knoll, Beckenham.
1908. *Berry, Arthur J. 14 Regent-street, Cambridge.
1904. §Berry, Professor R. A., F.I.C. West of Scotland Agricultural College, 6 Blythswood-square, Glasgow.
1914. ‡Berry, Professor R. J. A., M.D. The University, Carlton, Melbourne.
1905. ‡Bertrand, Captain Alfred. Champel, Geneva.
1916. §Bestow, C. H., F.R.M.S. Melford House, Upper Clapton-road, E. 5.
1913. ‡Bethune-Baker, G. T. 19 Clarendon-road, Edgbaston, Birmingham.

Year of Election.

1880. *Bevan, Rev. James Oliver, M.A., F.S.A., F.G.S. Chillenden Rectory, Canterbury.
1884. *Beverley, Michael, M.D. The Shrubbery, Scole, Norfolk.
1913. ‡Bewlay, Hubert. The Lindens, Moseley, Birmingham.
1903. ‡Bickerdike, C. F. 1 Boverney-road, Honor Oak Park, S.E. 23.
1870. ‡Bicketon, Professor A. W. 18 Pembridge-mansions, Moscow-road, W. 2.
1888. *Bidder, George Parker, D.Sc. Cavendish Corner, Cambridge.
1911. ‡Biles, Sir John H., LL.D., D.Sc. (Pres. G, 1911), Professor of Naval Architecture in the University of Glasgow. 175 West George-street, Glasgow.
1898. ‡Billington, Charles. Heimath, Longport, Staffordshire.
1901. *Bilsland, Sir William, Bart., J.P. 28 Park-circus, Glasgow.
1908. *Bilton, Edward Barnard. Graylands, Wimbledon Common, S.W.
1910. *Birchenough, C., M.A. 103 Tonbridge-road, Maidstone.
1915. *Birley, J. Harold. Cambridge-street, Manchester.
1913. ‡Birtwistle, G. Pembroke College, Cambridge.
1904. ‡Bishop, A. W. Edwinstowe, Chaucer-road, Cambridge.
1919. *Bishop, Ed. E. Fashoda, Cherminster-road, Bournemouth.
1906. ‡Bishop, J. L. Yarrow Lodge, Waldegrave-road, Teddington.
1910. ‡Bisset, John. Thornhill, Insch, Aberdeenshire.
1886. *Bixby, General W. H. 508 Federal-building, Chicago, Ill., U.S.A.
1914. *Black, S. G. Glenormiston, Glenormiston South, Victoria, Australia.
1909. ‡Black, W. J., Principal of Manitoba Agricultural College, Winnipeg, Canada.
1901. §Black, W. P. M. 136 Wellington-street, Glasgow.
1916. *Blackburn, Miss K. B., M.Sc. Armstrong College, Newcastle-on-Tyne.
1916. ‡Blackett, Lieut.-Colonel W. C. Acorn House, Sacriston, near Durham.
1903. *Blackman, F. F., M.A., D.Sc., F.R.S. (Pres. K, 1908.) St. John's College, Cambridge.
1908. ‡Blackman, Professor V. H., M.A., Sc.D., F.R.S. Imperial College of Science and Technology, S.W. 7.
1913. *Blackwell, Miss Elsie M., M.Sc. 16 Stanley-avenue, Birkdale, Southport.
1909. ‡Blaikie, Leonard, M.A. Civil Service Commission, Burlington-gardens, W. 1.
1920. *Blair, Douglas P., M.B. 40 South Methven-street, Perth.
1910. ‡Blair, Sir R., M.A. London County Council, Spring-gardens, S.W. 1.
1902. ‡Blake, Robert F., F.I.C. Queen's College, Belfast.
1914. ‡Blakemore, Mrs. D. M. Wawona, Cooper-street, Burwood, N.S.W.
1914. ‡Blakemore, G. H. Wawona, Cooper-street, Burwood, N.S.W.
1920 M Blakiston, C. H. Eton College, Windsor.
1905. ‡Blamires, Mrs. Bradley Lodge, Huddersfield.
1904. ‡Blanc, Dr. Gian Alberto. Istituto Fisico, Rome.
1915. ‡Bland, J. Arthur. Thornfield, Baxter-road, Sale.
1884. *Blandy, William Charles, M.A. 1 Friar-street, Reading.
1887. *Bles, Edward J., M.A., D.Sc. Elterholm, Madingley-road, Cambridge.
1884. *Blish, William G. Niles, Michigan, U.S.A.
1913. ‡Blofield, Rev. S., B.A. Saltley College, Birmingham.
1902. ‡Blount, Bertram, F.I.C. 76 & 78 York-street, Westminster, S.W. 1.
1888. ‡Bloxsom, Martin, B.A., M.Inst.C.E. 4 Lansdowne-road, Crumpsall Green, Manchester.

Year of Election.

1909. ‡Blumfeld, Joseph, M.D. 35 Harley-street, W. 1.
1887. *Boddington, Henry, J.P. Pownall, Wilmslow, Manchester.
1908. ‡Boeddicker, Otto, Ph.D. Birr Castle Observatory, Birr, Ireland.
1915. ‡Bohr, N. Physical Laboratory, The University, Manchester.
1887. *Boissevain, Gideon Maria. 4 Tesselschade-straat, Amsterdam.
1915. ‡Bolivar, Mrs. Anna de. 75 Clarendon-road, High-street, Manchester.
1911. ‡Bolland, B. G. C. Department of Agriculture, Cairo, Egypt.
1898. §Bolton, H., M.Sc., F.R.S.E. The Museum, Queen's-road, Bristol.
1894. §Bolton, John, F.R.G.S. 22 Hawes-road, Bromley, Kent.
1919. §Bolton, R. A. R. 60 Ranelagh-gardens, S.W. 1.
1898. *Bonar, James, M.A., LL.D. (Pres. F, 1898; Council, 1899–1905.) The Mint, Ottawa, Canada.
1909. ‡Bonar, Thomson, M.D. 114 Via Babuino, Piazza di Spagna, Rome.
1912. *Bond, C. I., C.M.G., F.R.C.S. 10 Springfield-road, Leicester.
1914. ‡Bond, Mrs. C. I. 10 Springfield-road, Leicester.
1909. ‡Bond, J. H. R., M.B. 167 Donald-street, Winnipeg, Canada.
1908. ‡Bone, Professor W. A., D.Sc., F.R.S. (Pres. B, 1915; Council, 1915– .) Imperial College of Science and Technology, S.W. 7.
1871. *Bonney, Rev. Thomas George, Sc.D., LL.D., F.R.S., F.S.A., F.G.S. (President, 1910; Secretary, 1881–85; Pres. C, 1886.) 9 Scroope-terrace, Cambridge.
1911. ‡Bonny, W. Naval Store Office, The Dockyard, Portsmouth.
1893. ‡Boot, Sir Jesse, Bart. Carlyle House, 18 Burns-street, Nottingham.
1883. ‡Booth, James. Hazelhurst, Turton.
1910. ‡Booth, John, M.C.E., B.Sc. The Gables, Berkeley-street, Hawthorn, Victoria, Australia.
1883. ‡Boothroyd, Benjamin. Weston-super-Mare.
1912. ‡Borgmann, Professor J. J., D.Ph., LL.D. Physical Institute, The University, Petrograd.
1882. §Borns, Henry, Ph.D. 5 Sutton Court-road, Chiswick, W. 4.
1901. ‡Borradaile, L. A., M.A. Selwyn College, Cambridge.
1903. *Bosanquet, Robert C., M.A., Professor of Classical Archæology in the University of Liverpool. Institute of Archæology, 40 Bedford-street, Liverpool.
1896. ‡Bose, Professor J. C., C.I.E., M.A., D.Sc. Calcutta, India.
1916. §Boswell, P. G. H., O.B.E., D.Sc., F.G.S., George Herdman Professor of Geology in the University of Liverpool.
1881. §Bothamley, Charles H., M.Sc., F.I.C., F.C.S., Education Secretary, Somerset County Council, Weston-super-Mare.
1871. *Bottomley, James Thomson, M.A., LL.D., D.Sc., F.R.S., F.R.S.E., F.C.S. 13 University-gardens, Glasgow.
1892. *Bottomley, W. B., M.A., Professor of Botany in King's College Strand, W.C. 2.
1909. ‡Boulenger, C. L., M.A., D.Sc. The University, Birmingham.
1905. ‡Boulenger, G. A., LL.D., F.R.S. (Pres. D, 1905.) 8 Courtfield-road, S.W. 7.
1905. ‡Boulenger, Mrs. 8 Courtfield-road, S.W. 7.
1903. §Boulton, W. S., D.Sc., F.G.S. (Pres. C, 1916.), Professor of Geology in the University of Birmingham.
1911. ‡Bourdillon, R. Balliol College, Oxford.
1883. ‡Bourne, Sir A. G., K.C.I.E., D.Sc., F.R.S., F.L.S. Middlepark Paignton, South Devon.

Year of Election.

1893. *Bourne, G. C., M.A., D.Sc., F.R.S., F.L.S. (Pres. D, 1910; Council, 1903-09; Local Sec. 1894), Linacre Professor of Comparative Anatomy in the University of Oxford. Savile House, Mansfield-road, Oxford.
1904. *Bousfield, E. G. P. 7 Harley-street, W.
1913. ‡Bowater, Sir W. H. Elm House, Arthur-road, Edgbaston, Birmingham.
1913. ‡Bowater, Captain William. 20 Russell Mond, Moseley, Birmingham.
1881. *Bower, F. O., Sc.D., F.R.S., F.R.S.E., F.L.S. (Pres. K, 1898, 1914; Council, 1900-06), Regius Professor of Botany in the University of Glasgow.
1898. *Bowker, Arthur Frank, F.R.G.S., F.G.S. Whitehill, Wrotham, Kent.
1898. ‡Bowley, A. L., M.A. (Pres. F, 1906; Council, 1906-11.) North-court-avenue, Reading.
1880. ‡Bowly, Christopher. Cirencester.
1887. ‡Bowly, Mrs. Christopher. Cirencester.
1899. *Bowman, Herbert Lister, M.A., D.Sc., F.G.S., Professor of Mineralogy in the University of Oxford. Magdalen College, Oxford.
1899. *Bowman, John Herbert. Greenham Common, Newbury.
1887. §Box, Alfred Marshall. 14 Magrath-avenue, Cambridge.
1919. *Boyd, Professor D. R. University College, Southampton.
1901. ‡Boyd, David T. Rhinsdale, Ballieston, Lanark.
1915. *Boyd, H. de H. Care of Southern Cotton Oil Company, Trafford Park, Manchester.
1892. ‡Boys, Charles Vernon, F.R.S. (Pres. A, 1903; Council, 1893-99, 1905-08.) 66 Victoria-street, S.W. 1.
1872. *Brabrook, Sir Edward, C.B., F.S.A. (Pres. H, 1898; Pres. F, 1903; Council, 1903-10, 1911-19.) Langham House, Wallington, Surrey.
1894. *Braby, Ivon. Helena, Alan-road, Wimbledon, S.W.
1915. ‡Bradley, F. E., M.A. Bank of England-chambers, Manchester.
1893. ‡Bradley, F. L. Ingleside, Malvern Wells.
1904. *Bradley, Gustav, Borough Surveyor, Bridlington.
1903. *Bradley, O. Charnock, D.Sc., M.D., F.R.S.E. Royal Veterinary College, Edinburgh.
1892. ‡Bradshaw, W. Carisbrooke House, The Park, Nottingham.
1863. ‡Brady, George S., M.D., LL.D., F.R.S. Park Hurst, Endcliffe, Sheffield.
1911. §Bragg, Sir W. H., K.B.E., M.A., F.R.S. (Council, 1913-17), Professor of Physics in the University of London. University College, W.C. 1.
1905. §Brakhan, A. 6 Montague-mansions, Portman-square, W. 1.
1906. ‡Branfield, Wilfrid. 4 Victoria-villas, Upperthorpe, Sheffield.
1885. *Bratby, William, J.P. Alton Lodge, Lancaster Park, Harrogate.
1905. ‡Brausewetter, Miss. Roedean School, near Brighton.
1909. §Bremner, Alexander. 38 New Broad-street, E.C. 2.
1905. ‡Bremner, R. S. Westminster-chambers, Dale-street, Liverpool.
1905. ‡Bremner, Stanley. Westminster-chambers, Dale-street, Liverpool.
1913. *Brenchley, Miss Winifred E., D.Sc., F.L.S. Rothamsted Experimental Station, Harpenden, Herts.
1902. *Brereton, Cloudesley. 7 Lyndhurst-road, Hampstead, N.W. 3.
1909. *Breton, Miss Adela C. 15 Camden-cresent, Bath. To be forwarded.
1908. ‡Brickwood, Sir John. Branksmere, Southsea.
1907. *Bridge, Henry Hamilton. Fairfield House, Droxford, Hants.

Year of Election.

1912. ‡Bridgman, F. J., F.L.S. Zoological Department, University College, W.C. 1.
1913. ‡Brierley, Leonard H. 11 Ampton-road, Edgbaston, Birmingham.
1919. §Brierley, W. B. Rothamsted Experimental Station, Harpenden, Herts.
1904. *Briggs, William, M.A., LL.D., F.R.A.S. Burlington House, Cambridge.
1909. *Briggs, Mrs. William. Burlington House, Cambridge.
1908. ‡*Brindley, H. H.* 4 *Devana-terrace, Cambridge.*
1893. ‡Briscoe, Albert E., B.Sc., A.R.C.Sc. The Hoppet, Little Baddow, Chelmsford.
1904. ‡Briscoe, J. J. Bourn Hall, Bourn, Cambridge.
1905. §Briscoe, Miss. Bourn Hall, Bourn, Cambridge.
1879. *Brittain, W. H., J.P., F.R.G.S. Storth Oaks, Sheffield.
1905. ‡Brock, Dr. B. G. P.O. Box 216, Germiston, Transvaal.
1907. ‡Brockington, W. A., M.A. Birstall, Leicester.
1915. ‡*Brocklehurst, F.* 33 *King-street, Manchester.*
1883. *Brodie-Hall, Miss W. L. Havenwood, Peaslake, Gomshall, Surrey.
1903. ‡Brodrick, Harold, M.A., F.G.S. (Local Sec. 1903.) 7 Aughton-road, Birkdale, Southport.
1913. ‡Brodrick, Mrs. Harold. 7 Aughton-road, Birkdale, Southport.
1904. ‡Bromwich, T. J. I'A., M.A., F.R.S. 1 Selwyn-gardens, Cambridge.
1906. ‡Brook, Stanley. 18 St. George's-place, York.
1911. §Brooke, Colonel Charles K., F.R.G.S. Army and Navy Club, Pall Mall, S.W. 1.
1915. ‡Brooks, Colin. 7 Cedar-street, Southport.
1883. *Brooks, F. T. 31 Tenison-avenue, Cambridge.
1883. *Brough, Mrs. Charles S. 13 St. Andrew's-road, Southsea.
1886. ‡Brough, Joseph, LL.D., Professor of Logic and Philosophy in University College, Aberystwyth.
1905. ‡Brown, A. R. Trinity College, Cambridge.
1863. *Brown, Alexander Crum, M.D., LL.D., F.R.S., F.R.S.E., V.P.C.S. (Pres. B, 1874; Local Sec. 1871.) 8 Belgrave-crescent, Edinburgh.
1905. §Brown, Professor Ernest William, M.A., D.Sc., F.R.S. Yale University, New Haven, Conn., U.S.A.
1914. ‡Brown, F. G., B.A., B.Sc. Naval College, North Geelong, Victoria, Australia.
1903. ‡Brown, F. W. 6 Rawlinson-road, Southport.
1914. ‡Brown, Rev. George, D.D. Kinawanua, Gordon, N.S.W.
1870. §Brown, Horace T., LL.D., F.R.S., F.C.S. (Pres. B, 1899; Council, 1904–11.) 52 Nevern-square, S.W. 5.
1881. *Brown, John, M.D. Liesbreek-road, Mowbray, Cape of Good Hope.
1895. *Brown, John Charles. 39 Burlington-road, Sherwood, Nottingham.
1882. *Brown, Mrs. Mary. Liesbreek-road, Mowbray, Cape of Good Hope.
1901. ‡Brown, R. N. Rudmose, D.Sc. The University, Sheffield.
1908. §Brown, Sidney G., F.R.S. 52 Kensington Park-road, W. 11.
1905. §Brown, Mrs. Sidney G. 52 Kensington Park-road, W. 11.
1910. *Brown, Sidney J. R. 52 Kensington Park-road, W. 11.
1912. ‡Brown, T. Graham. The University, Liverpool.
1884. ‡Brown, W. G. University of Missouri, Columbia, Missouri, U.S.A.
1908. ‡Brown, William, B.Sc. 48 Dartmouth-square, Dublin.
1912. ‡Brown, Dr. William, D.Sc. 14 Welbeck-street, W. 1.
1906. §Browne, Charles E., B.Sc. Christ's Hospital, West Horsham.

Year of Election.

1900. *Browne, Frank Balfour, M.A., F.R.S.E., F.Z.S. Oaklands, Fenstanton, St. Ives, Hunts.
1908. ‡Browne, Rev. Henry, M.A., Professor of Greek in University College, Dublin.
1896. *Browne, H. T. Doughty. St. Bernards, Caterham.
1879. ‡Browne, Sir J. Crichton, M.D., LL.D., F.R.S., F.R.S.E. 45 Hans-place, S.W. 1.
1905. *Browne, James Stark, F.R.A.S. Hanmer House, Mill Hill Park, W. 3.
1918. ‡Brownen, George, F.G.S. Talnas, Grove-road, Christchurch, Hants.
1883. ‡Browning, Oscar, M.A. King's College, Cambridge.
1912. ‡Browning, T. B., M.A. 18 Bury-street, Bloomsbury, W.C. 1.
1893. ‡Bruce, William S., LL.D., F.R.S.E. Scottish Oceanographical Laboratory, Surgeons' Hall, Edinburgh.
1900. *Brumm, Charles. Edendale, Whalley-road, Whalley Range, Manchester.
1897. *Brush, Charles F. Cleveland, Ohio, U.S.A.
1886. *Bryan, G. H., D.Sc., F.R.S., Professor of Mathematics in University College, Bangor.
1919. *Bryan, Miss M. A. Plas Gwyn, Bangor.
1894. ‡Bryan, Mrs. R. P. Plas Gwyn, Bangor.
1884. *Bryce, Rev. Professor George, D.D., LL.D. Kilmadock, Winnipeg, Canada.
1909. ‡Bryce, Thomas H., M.D., Professor of Anatomy in the University of Glasgow. 2 The College, Glasgow.
1902. *Bubb, Miss E. Maude. Ullenwood, near Cheltenham.
1890. §Bubb, Henry. Ullenwood, near Cheltenham.
1902. *Buchanan, Miss Florence, D.Sc. University Museum, Oxford.
1905. ‡Buchanan, Hon. Sir John. Clareinch, Claremont, Cape Town.
1909. ‡Buchanan, W. W. P.O. Box 1658, Winnipeg, Canada.
1914. ‡Buck, E. J. Menzies' Hotel, Melbourne.
1913. ‡Buckland, H. T. 21 Yateley-road, Edgbaston, Birmingham.
1884. *Buckmaster, Charles Alexander, M.A., F.C.S. 16 Heathfield-road, Mill Hill Park, W. 3.
1904. ‡Buckwell, J. C. North Gate House, Pavilion, Brighton.
1919. §Bulfin, Ignatius. Tramways Office, Lansdowne-cresent, Bournemouth.
1893. §Bulleid, Arthur, F.S.A. Dymboro, Midsomer Norton, Bath.
1913. *Bulleid, C. H. University College, Nottingham.
1913. *Buller, A. H. Reginald, Professor of Botany in the University of Manitoba, Winnipeg.
1916. ‡Bulman, H. F. Moss Garth, Portinscale, Keswick.
1909. ‡Bulyea, The Hon. G. H. V. Edmonton, Alberta, Canada.
1914. ‡Bundey, Miss E. M. Molesworth-street, North Adelaide, South Australia.
1905. ‡Burbury, Mrs. A. A. 15 Melbury-road, W. 14.
1905. ‡Burbury, Miss A. D. 15 Melbury-road, W. 14.
1881. ‡Burdett-Coutts, William Lehmann, M.P. 1 Stratton-street, Piccadilly, W. 1.
1905. ‡Burdon, E. R., M.A. Ikenhilde, Royston, Herts.
1913. ‡Burfield, Stanley Thomas. Zoology Department, The University, Liverpool.
1919. §Burgess, H. F. J., F.R.G.S. 62 Thornbury-road, Isleworth.
1913. *Burgess, J. Howard. Shide, Newport, Isle of Wight.
1894. ‡*Burke, John B. B. Trinity College, Cambridge.*

Year of Election.

1884. *Burland, Lieut.-Colonel Jeffrey H. 342 Sherbrooke-street West, Montreal, Canada.
1915. §Burlin, Adolph L., Ph.D. The Abbey Laboratory, Burton-on-Trent.
1904. ‡Burn, R. H. 21 Stanley-crescent, Notting-hill, W. 11.
1909. ‡Burns, F. D. 203 Morley-avenue, Winnipeg, Canada.
1914. *Burns, Colonel James. Gowan Brae, Parramatta, N.S.W.
1908. ‡Burnside, W. Snow, D.Sc., Professor of Mathematics in the University of Dublin. 35 Raglan-road, Dublin.
1919. *Burrell, Mrs. T. Gaze. Keydon Lodge, Poole-road, Bournemouth.
1909. ‡Burrows, Theodore Arthur. 187 Kennedy-street, Winnipeg, Canada.
1910. ‡Burt, Cyril. L.C.C. Education Offices, Victoria Embankment, W.C. 2.
1919. *Burton, Mrs. Alice. 143 Whitehall-court, S.W. 1.
1909. ‡Burton, E. F. 129 Howland-avenue, Toronto, Canada.
1911. ‡Burton, J. H. Agriculture Office, Weston-super-Mare.
1892. ‡Burton-Brown, Colonel A., R.A., F.G.S. Royal Societies Club, St. James's-street, S.W. 1.
1904. ‡Burtt, Arthur H., D.Sc. 4 South View, Holgate, York.
1906. ‡Burtt, Philip. Swarthmore, St. George's-place, York.
1887. *Bury, Henry. Mayfield House, Farnham, Surrey.
1899. ‡Bush, Anthony. 43 Portland-road, Nottingham.
1895. ‡Bushe, Colonel C. K., F.G.S. 19 Cromwell-road, S.W. 7.
1908. *Bushell, W. F. Rossall School, Fleetwood.
1910. ‡*Butcher, Miss.* 25 *Earl's Court-square, S.W.*
1916. §Butler, George Grey, J.P. Ewart Park, Wooler, Northumberland.
1913. *Butler, W. Waters. Southfield, Norfolk-road, Edgbaston, Birmingham.
1915. *Butterworth, Charles F. Waterloo, Poynton, Cheshire.
1884. *Butterworth, W. Carisbrooke, Rhiw-road, Colwyn Bay, North Wales.
1919. §Buxton, Captain L. H. Dudley. University Museum, Oxford.
1899. ‡Byles, Arthur R. 'Bradford Observer,' Bradford, Yorkshire.

1913. §Cadbury, Edward. Westholme, Selly Oak, Birmingham.
1913. ‡Cadbury, W. A. Wast Hills, King's Norton.
1892. ‡Cadell, H. M., B.Sc., F.R.S.E. Grange, Linlithgow.
1913. ‡Cadman, Sir John, K.C.M.G., D.Sc., Professor of Mining in the University of Birmingham. 67 Wellington-road, Edgbaston, Birmingham.
1913. ‡Cahill, J. R. 49 Hanover Gate-mansions, Regent's Park, N.W. 1.
1912. §Caine, Nathaniel. Spital, Cheshire.
1901. ‡*Caldwell, Hugh. Blackwood, Newport, Monmouthshire.*
1907. ‡Caldwell, K. S. St. Bartholomew's Hospital, E.C. 1.
1897. ‡Callendar, Hugh L., C.B.E., M.A., LL.D., F.R.S. (Pres. A, 1912; Council, 1900-06), Professor of Physics in the Imperial College of Science and Technology, S.W. 7.
1911. ‡Calman, W. T., D.Sc. British Museum (Natural History), Cromwell-road, S.W. 7.
1916. ‡Calvert, Joseph. Park View, Middlesbrough.
1914. ‡Cambage, R. H., F.L.S. Department of Mines, Sydney, N.S.W.
1911. ‡Cameron, Alexander T. Physiological Department, University of Manitoba, Winnipeg.
1857. ‡Cameron, Sir Charles A., C.B., M.D. 51 Pembroke-road, Dublin.
1909. ‡Cameron, D. C. 65 Roslyn-road, Winnipeg, Canada.

Year of Election.

1896. §Cameron, Irving H., LL.D., Professor of Surgery in the University of Toronto. 307 Sherbourne-street, Toronto, Canada.
1909. ‡Cameron, Hon. Mr. Justice J. D. Judges' Chambers, Winnipeg, Canada.
1901. §Campbell, Archibald. Argyll Lodge, 62 Albert-drive, Pollokshields, Glasgow.
1897. ‡Campbell, Colonel J. C. L. Achalader, Blairgowrie, N.B.
1909. *Campbell, R. J. Holdenhurst, Hendon-avenue, Church End, Finchley, N. 3.
1909. ‡Campbell, Mrs. R. J. Holdenhurst, Hendon-avenue, Church End, Finchley, N. 3.
1902. ‡*Campbell, Robert.* 21 *Great Victoria-street, Belfast.*
1912. ‡Campbell, Dr. Robert. Geological Department, The University, Edinburgh.
1890. ‡Cannan, Professor Edwin, M.A., LL.D., F.S.S. (Pres. F, 1902.) 11 Chadlington-road, Oxford.
1904. ‡Capell, Rev. G. M. Passenham Rectory, Stony Stratford.
1911. ‡Capon, R. S. 49A Rodney-street, Liverpool.
1894. ‡Capper, D. S., M.A., Professor of Mechanical Engineering in King's College, W.C. 1.
1887. ‡Capstick, J. W. Trinity College, Cambridge.
1896. *Carden, H. Vandaleur. 19 Kenilworth-court, Putney, S.W. 15.
1913. ‡Carlier, E. Wace, M.Sc., M.D., F.R.S.E., Professor of Physiology in the University of Birmingham. The University, Edmund-street, Birmingham.
1914. ‡Carne, J. E. Mines Department, Sydney, N.S.W.
1913. §Carpenter, Charles. 157 Victoria-street, S.W. 1.
1913. *Carpenter, G. D. H., M.B. 19 Bardwell-road, Oxford.
1902. ‡Carpenter, G. H., B.Sc., Professor of Zoology in the Royal College of Science, Dublin.
1906. *Carpenter, Professor H. C. H., M.A., Ph.D., F.R.S., 30 Murray-road, Wimbledon, S.W. 19.
1905. ‡Carpmael, Edward, F.R.A.S., M.Inst.C.E. The Ivies, 118 St. Julian's Farm-road, West Norwood, S.E. 27.
1912. *Carr, H. Wildon, D.Litt. 107 Church-street, Chelsea, S.W. 3.
1910. ‡Carr, Henry F. Broadparks, Pinhoe, near Exeter.
1893. ‡Carr, J. Wesley, M.A., F.L.S., F.G.S., Professor of Biology in University College, Nottingham.
1906. *Carr, Richard E. Sylvan Mount, Sylvan-road, Norwood, S.E. 19.
1889. ‡Carr-Ellison, John Ralph. Hedgeley, Alnwick.
1911. ‡Carruthers, R. G., F.G.S. Geological Survey Office, 33 George-square, Edinburgh.
1867. ‡Carruthers, William, F.R.S., F.L.S., F.G.S. (Pres. D, 1886.) 44 Central-hill, Norwood, S.E. 19.
1886. ‡Carslake, J. Barham. (Local Sec. 1886.) 30 Westfield-road, Birmingham.
1899. ‡Carslaw, H. S., D.Sc., Professor of Mathematics in the University of Sydney, N.S.W.
1914. §Carson, Rev. James. The Manse, Cowper, N.S.W.
1919. §Carter, A. J. The Haven, Millbrook-road, Southampton.
1919. §Carter, William. The Oaks, Parkstone, Dorset.
1896. ‡Cartwright, Miss Edith G. 21 York Street-chambers, Bryanston-square, W. 1.
1878. *Cartwright, Ernest H., M.A., M.D. Oakdene, Boynewood-road, Tunbridge Wells.
1870. §Cartwright, Joshua, M.Inst.C.E., F.S.I. Albion-place, Bury, Lancashire.

Year of Election.

1862. ‡Carulla, F. J. R. 84 Rosehill-street, Derby.
1894. ‡Carus, Dr. Paul. La Salle, Illinois, U.S.A.
1913. §Carus-Wilson, Cecil, F.R.S.E., F.G.S. Altmore, Waldegrave-park, Strawberry Hill, Twickenham.
1901. ‡Carver, Thomas A. B., D.Sc., Assoc.M.Inst.C.E. 9 Springfield-road, Dalmarnock, Glasgow.
1899. *Case, J. Monckton. Department of Lands (Water Branch), Victoria, British Columbia.
1919. §Casson, S. 8 Bedford-park, Chiswick, W.
1908. *Cave, Charles J. P., M.A. Ditcham Park, Petersfield.
1919. *Cave-Browne-Cave, Commander T. R. Burnage, Streatham Common, S.W. 16.
1910. ‡Chadburn, A. W. Brincliffe Rise, Sheffield.
1905. *Challenor, Bromley, M.A. The Firs, Abingdon.
1905. *Challenor, Miss E. M. The Firs, Abingdon.
1910. *Chalmers, S. D. 13 Ribblesdale-road, Hornsey, N. 8.
1913. ‡Chamberlain, Neville. Westbourne, Edgbaston, Birmingham.
1914. §Chamberlin, Dr. R. T. Geological Department, University of Chicago, U.S.A.
1913. ‡Chambers, Miss Beatrice Anne. Glyn-y-mêl, Fishguard.
1901. §Chamen, W. A. South Wales Electrical Power Distribution Company, Royal-chambers, Queen-street, Cardiff.
1905. ‡Champion, G. A. Haraldene, Chelmsford-road, Durban, Natal.
1881. *Champney, John E. 27 Hans-place, S.W. 1.
1908. ‡Chance, Sir Arthur, M.D. 90 Merrion-square, Dublin.
1916. *Chance, C. F., M.A. 12 Arthur-road, Edgbaston, Birmingham.
1888. ‡Chandler, S. Whitty, B.A. St. George's, Cecil-road, Boscombe.
1907. *Chapman, Alfred Chaston, F.I.C. 8 Duke-street, Aldgate, E.C. 3.
1919. §Chapman, Arthur. W. 68 Geraldine-road, S.W. 18.
1902. *Chapman, D. L., M.A., F.R.S. Jesus College, Oxford.
1914. §Chapman, H. G., M.D. Department of Physiology, The University, Sydney, N.S.W.
1910. ‡Chapman, J. E. Kinross.
1912. *Chapman, Sydney, M.A., D.Sc., F.R.S. Trinity College, Cambridge.
1899. ‡Chapman, Sir Sydney J., K.B.E., C.B. (Pres. F, 1909), Board of Trade, Great George-street, S.W. 1.
1916. ‡Charlesworth, Dr. J. K. Queen's University, Belfast.
1905. ‡Chassigneux, E. 12 Tavistock-road, Westbourne-park, W. 11.
1904. *Chattaway, F. D., M.A., D.Sc., Ph.D., F.R.S. 151 Woodstock-road, Oxford.
1886. *Chattock, A. P., D.Sc. Heathfield Cottage, Crowcombe, Somerset.
1904. *Chaundy, Theodore William, M.A. Christ Church, Oxford.
1913. ‡Cheesman, Miss Gertrude Mary. The Crescent, Selby.
1900. *Cheesman, W. Norwood, J.P., F.L.S. The Crescent, Selby.
1874. *Chermside, Lieut.-General Sir Herbert, R.E., G.C.M.G., C.B. Pepper Arden, Northallerton, Yorkshire.
1908. ‡Cherry, Right Hon. Lord Justice. 92 St. Stephen's Green, Dublin.
1910. ‡Chesney, Miss Lilian M., M.B. 381 Glossop-road, Sheffield.
1879. *Chesterman, W. Belmayne, Sheffield.
1919. §Chibnall, A. C. Cedar House, Chiswick Mall, S.W. 4.
1911. *Chick, Miss H., D.Sc. Chestergate, Park-hill, Ealing, W. 5.
1908. ‡Chill, Edwin, M.D. Westleigh, Mattock-road, Ealing, W. 5.
1833. ‡Chinery, Edward F., J.P. Lymington.
1919. §Chinnery, E. W. Pearosn. Christ's College, Cambridge.
1894. ‡Chisholm, G. G., M.A., B.Sc., F.R.G.S. (Pres. E, 1907.) 12 Hallhead-road, Edinburgh.

Year of Election.

1899. §Chitty, Edward. Sonnenberg, Castle-avenue, Dover.
1899. ‡Chitty, Mrs. Edward. Sonnenberg, Castle-avenue, Dover.
1904. §Chivers, John, J.P. Wychfield, Cambridge.
1882. ‡Chorley, George. Midhurst, Sussex.
1909. ‡Chow, H. H., M.D. 263 Broadway, Winnipeg, Canada.
1893. *Chree, Charles, Sc.D., F.R.S. Kew Observatory, Richmond, Surrey.
1913. ‡*Christie, Dr. M. G. Post Office House, Leeds.*
1900. *Christie, R. J. Duke-street, Toronto, Canada.
1875. *Christopher, George, F.C.S. Thorncroft, Chislehurst.
1903. ‡Clapham, J. H., M.A. King's College, Cambridge.
1901. §Clark, Archibald B., M.A., Professor of Political Economy in the University of Manitoba, Winnipeg, Canada.
1905. *Clark, Cumberland, F.R.G.S. 22 Kensington Park-gardens, W. 11.
1907. *Clark, Mrs. Cumberland. 22 Kensington Park-gardens, W. 11.
1877. *Clark, F. J., J.P., F.L.S. Netherleigh, Street, Somerset.
1902. ‡Clark, G. M. South African Museum, Cape Town.
1881. *Clark, J. Edmund, B.A., B.Sc. Asgarth, Riddlesdown-road, Purley, Surrey.
1909. ‡Clark, J. M., M.A., K.C. The Kent Building, 156 Yonge-street, Toronto, Canada.
1908. ‡Clark, James, B.Sc., Ph.D. Newtown School, Waterford, Ireland.
1908. ‡Clark, John R. W. Brothock Bank House, Arbroath, Scotland.
1919. *Clark, L. H. 3 Cinque Port-villas, Rope Walk, Rye.
1901. *Clark, Robert M., B.Sc., F.L.S. 27 Rubislaw Den South, Aberdeen.
1907. *Clarke, E. Russell, C.B.E. 11 King's Bench-walk, Temple, E.C. 4.
1902. *Clarke, Miss Lilian J., D.Sc., F.L.S. Chartfield Cottage, Brasted Chart, Kent.
1889. *Clayden, A. W., M.A., F.G.S. 5 The Crescent, Mount Radford, Exeter.
1909. §Cleeves, Frederick, F.Z.S. 120 Fenchurch-street, E.C. 3.
1909. ‡Cleeves, W. B. Public Works Department, Government-buildings, Pretoria.
1914. §Clegg, Mrs. Florence M. Burong, Sussex-street, Ballarat, Victoria, Australia.
1915. ‡Clegg, John Gray. 22 St. John-street, Manchester.
1861. ‡Cleland, John, M.D., D.Sc., F.R.S. Drumclog, Crewkerne, Somerset.
1905. ‡Cleland, Mrs. Drumclog, Crewkerne, Somerset.
1905. ‡Cleland, Captain J. R. Drumclog, Crewkerne, Somerset.
1902. ‡Clements, Olaf P. Tana, St. Bernard's-road, Olton, Warwick.
1904. §Clerk, Sir Dugald, K.B.E., D.Sc., F.R.S., M.Inst.C.E. (Pres. G, 1908; Council, 1912– .) 57 and 58 Lincoln's Inn-fields, W.C. 2.
1909. ‡*Cleve, Miss. E. K. P. 74 Kensington Gardens-square, W. 2.*
1861. *Clifton, R. Bellamy, M.A., F.R.S., F.R.A.S. 3 Bardwell-road, Banbury-road. Oxford.
1906. §Close, Colonel Sir Charles, R.E., C.M.G., F.R.S., F.R.G.S. (Pres. E, 1911; Council, 1908–12.) Ordnance Survey Office, Southampton.
1914. ‡Close, J. Campbell. 217 Clarence-street, Sydney, N.S.W.
1919. §Clougher, Nugent M. 20 Craven-street, W.C. 2.
1883. *Clowes, Professor Frank, D.Sc., F.C.S. (Local Sec. 1893.) The Grange, College-road, Dulwich, S.E. 21.
1914. ‡Clowes, Mrs. The Grange, College-road, Dulwich, S.E. 21.
1912. §Clubb, Joseph A., D.Sc. Free Public Museum, Liverpool.
1891. *Coates, Henry, F.R.S.E. Corarder, Perth.
1911. §Cobbold, E. S., F.G.S. Church Stretton, Shropshire.

Year of Election

1908. *Cochrane, Miss Constance. The Downs, St. Neots.
1901. ‡*Cockburn, Sir John, K.C.M.G., M.D.* 10 *Gatestone-road, Upper Norwood, S.E.*
1883. ‡Cockshott, J. J. 24 Queen's-road, Southport.
1913. ‡Codd, J. Alfred. 7 Tettenhall-road, Wolverhampton.
1861. *Coe, Rev. Charles C., F.R.G.S. Whinsbridge, Grosvenor-road, Bournemouth.
1898. ‡Coffey, George. 5 Harcourt-terrace, Dublin.
1896. *Coghill, Percy de G. Sunnyside House, Prince's Park, Liverpool.
1914. ‡Coghill, Mrs. Una. Monomeath-avenue, Canterbury, Victoria, Australia.
1887. ‡Cohen, Professor J. B., F.R.S. The University, Leeds.
1901. *Cohen, R. Waley, B.A. 11 Sussex-square, W. 2.
1919. §Coignon, Miss C. 31 Ibbertson-terrace, Hyde Park, W.
1906. *Coker, Ernest George, M.A., D.Sc., F.R.S, M.Inst.C.E. (Pres. G, 1914.) Professor of Civil and Mechanical Engineering, University College, Gower-street, W.C. 1.
1914. ‡Coker, Mrs. 3 Farnley-road, Chingford, Essex.
1895. *Colby, William Henry. 80 Coldharbour-road, Redland, Bristol.
1913. ‡Cole, Professor F. J. University College, Reading.
1893. §Cole, Grenville A. J., F.R.S., F.G.S. (Pres. C, 1915), Professor of Geology in the Royal College of Science, Dublin.
1903. ‡Cole, Otto B. 551 Boylston-street, Boston, U.S.A.
1897. §Coleman, Professor A. P., M.A., Ph.D., F.R.S. (Pres. C, 1910.) 476 Huron-street, Toronto, Canada.
1899. ‡Collard, George. The Gables, Canterbury.
1892. ‡Collet, Miss Clara E. 7 Coleridge-road, N. 4.
1912. ‡Collett, J. M., J.P. Kimsbury House, Gloucester
1887. ‡Collie, J. Norman, Ph.D., F.R.S., Professor of Organic Chemistry in the University of London. 16 Campden-grove, W. 8.
1913. ‡Collinge, Walter E., M.Sc. The Gatty Marine Laboratory, The University, St. Andrews, N.B.
1916. §Collingwood, Arthur B. Lilburn Tower, Alnwick, Northumberland.
1861. *Collingwood, J. Frederick, F.G.S. 8 Oakley-road, Canonbury, N. 1.
1910. *Collins, S. Hoare. 9 Cavendish-place, Newcastle-on-Tyne.
1902. ‡Collins, T. R. Belfast Royal Academy, Belfast.
1917. ‡Collis, E. L., M.B. Factory Department, Home Office, S.W. 1.
1914. ‡Collum, Mrs. Anna Maria. 18 Northbrook-road, Leeson Park, Dublin.
1892. ‡Colman, Dr. Harold G. 1 Arundel-street, Strand, W.C. 2.
1910. *Colver, Robert, jun. Graham-road, Ranmoor, Sheffield.
1910. *Compton, Professor Robert Harold, B.A. National Botanic Gardens, Kirstenbosch, near Cape Town.
1912. §Conner, Dr. William. Solent Cliffs, Bournemouth.
1902. ‡Conway, Professor A. W., M.A., F.R.S. 25 Coliemore-road, Dalkey, Dublin.
1903. ‡Conway, R. Seymour, Litt.D., Professor of Latin in Owens College, Manchester.
1898. ‡Cook, Ernest H., D.Sc. 27 Berkeley-square, Clifton, Bristol.
1913 §Cook, Gilbert, M.Sc., Assoc.M.Inst.C.E. Engineering Department, The University, Manchester.
1876. *Cooke, Conrad W. The Pines, Langland-gardens, Hampstead, N.W. 3.
1911. ‡Cooke, J. H. 101 Victoria-road North, Southsea.
1919. §Cooke, Thurkill, B.A., Director of the Psychological Section of the Inventors' Union, 21 Spital-square, E.C.
1914. ‡Cooke, William Ternant, D.Sc. Fourth-avenue, East Adelaide, South Australia.

Year of Election.

1915. ‡Cookson, A. Ellis. 14 Hargreaves-buildings, Liverpool.
1916. *Cookson, Clive. Nether Warden, Hexham.
1914. ‡Cookson, Miss Isabel C. 154 Power-street, Hawthorn, Melbourne.
1888. ‡Cooley, George Parkin. Constitutional Club, Nottingham.
1899. *Coomaraswamy, A. K., D.Sc., F.L.S., F.G.S., Keeper of Indian Art, Museum of Fine Arts, Boston, Mass., U.S.A.
1903. ‡Cooper, Miss A. J. 22 St. John-street, Oxford.
1901. *Cooper, C. Forster, B.A. Trinity College, Cambridge.
1919. §Cooper, Ernest. 100 Old Christchurch-road, Bournemouth.
1911. §Cooper, W. E. Henwick Lodge, Worcester.
1912. ‡Cooper, W. F. The Laboratory, Rickmansworth-road, Watford.
1904. *Copeman, S. Monckton, M.D., F.R.S. Local Government Board, Whitehall, S.W. 1.
1909. ‡Copland, Mrs. A. Johns. Gleniffer, 50 Woodberry Down, N. 4.
1904. *Copland, Miss Louisa. 10 Wynnstay-gardens, Kensington, W.
1909. ‡Corbett, W. A. 207 Bank of Nova Scotia-building, Winnipeg, Canada.
1894. §Corcoran, Miss Jessie R. Rotherfield Cottage, Bexhill-on-Sea.
1916. ‡Corder, Percy. 1 Collingwood-terrace, Newcastle-on-Tyne.
1915. §Corker, James S. Care of Macintosh & Co., Ltd., Cambridge-street, Manchester.
1901. *Cormack, J. D., C.M.G., D.Sc., Professor of Civil Engineering and Mechanics in the University of Glasgow.
1893. *Corner, Samuel, B.A., B.Sc. Abbotsford House, Waverley-street, Nottingham.
1889. ‡Cornish, Vaughan, D.Sc., F.R.G.S. Woodville, Camberley.
1884. *Cornwallis, F. S. W., F.L.S. Linton Park, Maidstone.
1900. §Cortie, Rev. A. L., S.J., F.R.A.S. Stonyhurst College, Blackburn.
1905. ‡Cory, Professor G. E., M.A. Rhodes University College, Grahamstown, Cape Colony.
1909. *Cossar, G. C., M.A., F.G.S. Southview, Murrayfield, Edinburgh.
1910. ‡Cossar, James. 28 Coltbridge-terrace, Murrayfield, Midlothian.
1911. ‡Cossey, Miss, M.A. High School for Girls, Kent-road, Southsea.
1908. *Costello, John Francis, B.A. The Rectory, Ballymackey, Nenagh, Ireland.
1874. *Cotterill, J. H., M.A., F.R.S. Hillcrest, Parkstone, Dorset.
1908. ‡Cotton, Alderman W. F., D.L., J.P. Hollywood, Co. Dublin.
1908. ‡Courtenay, Colonel Arthur H., C.B., D.L. United Service Club, Dublin.
1919. §Cousins, W. J. 2 Dorlcote-road, Wandsworth, S.W. 18.
1911. ‡Couzens, Sir G. E., K.L.H. Glenthorne, Kingston-crescent, Portsmouth.
1908. ‡Cowan, P. C., B.Sc., M.Inst.C.E. 33 Ailesbury-road, Dublin.
1872. *Cowan, Thomas William, F.L.S., F.G.S. Sutherland House, Clevedon, Somersetshire.
1903. ‡Coward, H. Knowle Board School, Bristol.
1915. ‡Coward, H. F. Department of Scientific and Industrial Research, 16–18 Old Queen-street, Westminster, S.W. 1.
1900. ‡Cowburn, Henry. Dingle Head, Leigh, Lancashire.
1914. ‡Cowburn, Mrs. Dingle Head, Leigh, Lancashire.
1895. *Cowell, Philip H., M.A., D.Sc., F.R.S. 62 Shooters Hill-road, Blackheath, S.E. 3.
1899. ‡Cowper-Coles, Sherard. 1 and 2 Old Pye-street, Westminster, S.W. 1.
1913. ‡Cox, Professor A. Hubert, Ph.D., F.G.S. University College, Cardiff.
1909. ‡Cox, F. J. C. Anderson-avenue, Winnipeg, Canada.

Year of Election.

1905. ‡Cox, W. H. Royal Observatory, Cape Town.
1912. ‡Craig, D. D., M.A., B.Sc., M.B. The University, St. Andrews, N.B.
1911. ‡Craig, J. I. Homelands, Park-avenue, Worthing.
1908. ‡Craig, James, M.D. 18 Merrion-square North, Dublin.
1884. §Craigie, Major P. G., C.B., F.S.S. (Pres. F, 1900; Council, 1908–15.) Lympstone, Devon.
1906. ‡Craik, Right Hon. Sir Henry, K.C.B., LL.D., M.P. 5A Dean's-yard, Westminster, S.W. 1.
1908. *Cramer, W., Ph.D., D.Sc. Imperial Cancer Research Fund, Queen-square, Bloomsbury, W.C. 1.
1906. ‡Cramp, William, D.Sc. 33 Brazennose-street, Manchester.
1905. *Cranswick, W. F. P.O. Box 65, Bulawayo, Rhodesia.
1906. ‡Craven, Henry. (Local Sec. 1906.) Greenbank, West Lawn, Sunderland.
1905. ‡Crawford, Mrs. A. M. Marchmont, Rosebank, near Cape Town.
1905. ‡Crawford, Professor Lawrence, M.A., D.Sc., F.R.S.E. South African College, Cape Town.
1910. *Crawford, O. G. S. Tan House, Donnington, Berkshire.
1890. §Crawshaw, Charles B. Rufford Lodge, Dewsbury.
1883. *Crawshaw, Edward, F.R.G.S. 25 Tollington-park, N. 4.
1919. *Crew, F. A. E., M.B. 5 Lauriston-park, Edinburgh.
1876. *Crewdson, Rev. Canon George. Whitstead, Barton-road, Cambridge.
1887. *Crewdson, Theodore. Spurs, Styall, Handforth, Manchester.
1908. ‡Crocker, J. Meadmore. Albion House, Bingley, Yorkshire.
1905. §Croft, Miss Mary. Quedley, Shottermill.
1890. *Croft, W. B., M.A. Egmont, St. James'-lane, Winchester, Hampshire.
1878. *Croke, John O'Byrne, M.A. Clouncagh, Ballingarry Lacy, Co. Limerick.
1913. §Crombie, J. E., LL.D. Parkhill House, Dyce, Aberdeenshire.
1903. *Crompton, Holland. Oaklyn, Cross Oak-road, Berkhamsted.
1901. ‡Crompton, Colonel R. E., C.B., M.Inst.C.E. (Pres. G, 1901.) Kensington-court, W. 8.
1914. ‡Cronin, J. Botanic Gardens, South Yarra, Australia.
1916. ‡Crook, C. W., B.A., B.Sc. 10 West Bank, Stamford Hill, N. 16.
1887. ‡Crook, Henry T., M.Inst.C.E. Lancaster-avenue, Manchester.
1898. §Crooke, William, B.A. (Pres. H, 1910; Council, 1910–16.) Langton House, Charlton Kings, Cheltenham.
1897. *Crookshank, E. M., M.B. Saint Hill, East Grinstead, Sussex.
1909. ‡Crosby, Rev. E. H. Lewis, B.D. 36 Rutland-square, Dublin.
1905. ‡Crosfield, Hugh T. Walden, Coombe-road, Croydon.
1894. *Crosfield, Miss Margaret C. Undercroft, Reigate.
1904. §Cross, Professor Charles R. Massachusetts Institute of Technology, Cambridge, Mass., U.S.A.
1905. §Cross, Robert. 13 Moray-place, Edinburgh.
1904. *Crossley, Professor A. W., C.M.G., D.Sc., Ph.D., F.R.S. British Cotton Industry Research Assoc., 108 Deansgate, Manchester.
1908. ‡Crossley, F. W. 30 Molesworth-street, Dublin.
1897. *Crosweller, Mrs. W. T. Kent Lodge, Sidcup, Kent.
1920. MR Crow, William Bernard, B.Sc., F.L.S. University College, Newport-road, Cardiff.
1890. *Crowley, Ralph Henry, M.D. Sollershott W., Letchworth.
1910. ‡Crowther, C., M.A., Ph.D. Olympia Agricultural Co., The Bury, Offchurch, Leamington.
1910. *Crowther, James Arnold, Sc.D. St. John's College, Cambridge.

Year of Election.

1911. §Crush, S. T. Care of Messrs. Yarrow & Co., Ltd., Scotstoun West, Glasgow.
1916. ‡Cullen, W. H. The Castner-Kellner Alkali Company, Limited, Wallsend-on-Tyne.
1883. *Culverwell, Edward P., M.A., Professor of Education in Trinity College, Dublin.
1883. ‡Culverwell, T. J. H. Litfield House, Clifton, Bristol.
1914. *Cuming, James. 65 William-street, Melbourne.
1914. *Cuming, W. Fehon. Hyde-street, Yarraville, Victoria.
1911. ‡Cumming, Alexander Charles, D.Sc. Chemistry Department, University of Edinburgh.
1911. §Cummins, Major H. A., M.D., C.M.G., Professor of Botany in University College, Cork.
1861. *Cunliffe, Edward Thomas. The Parsonage, Handforth, Manchester.
1861. *Cunliffe, Peter Gibson. Dunedin, Handforth, Manchester.
1905. ‡Cunningham, Miss A. 2 St. Paul's-road, Cambridge.
1882. *Cunningham, Lieut.-Colonel Allan, R.E., A.I.C.E. 20 Essex-villas, Kensington, W. 8.
1905. ‡Cunningham, Andrew. Earlsferry, Campground-road, Mowbray, South Africa.
1911. ‡Cunningham, E. St. John's College, Cambridge.
1900. *Cunnington, William A., M.A., Ph.D., F.Z.S. 25 Orlando-road, Clapham Common, S.W. 4.
1916. ‡Cunnison, James. Penzance, Bristol-road, Selly Oak, Birmingham.
1912. §Cunynghame, Sir Henry H., K.C.B. (Pres. F, 1912.) Kingham Lodge, Kingham, Oxford.
1914. ‡Cunynghame, Lady. Kingham Lodge, Chipping Norton.
1914. ‡Curdie, Miss Jessie. Camperdown, Victoria.
1913. ‡Currall, A. E. Streetsbrook-road, Solihull, Birmingham.
1908. ‡*Currelly, C. T., M.A., F.R.G.S. United Empire Club*, 117 *Piccadilly, W.* 1.
1892. *Currie, James, M.A., F.R.S.E. Larkfield, Wardie-road, Edinburgh.
1902. ‡Curry, Professor M., M.Inst.C.E. 5 King's-gardens, Hove.
1912. §Curtis, Charles. Field House, Cainscross, Stroud, Gloucestershire.
1915. ‡Curtis, Raymond. Highfield, Leek, Staffordshire.
1907. ‡Cushny, Arthur R., M.D., F.R.S. (Pres. I, 1916), Professor of Pharmacology in the University of Edinburgh.
1913. ‡*Cutler, A. E.* 5 *Charlotte-road, Edgbaston, Birmingham.*
1913. ‡Czaplicka, Miss M. A. Somerville College, Oxford.

1910. ‡Dakin, Dr. W. J., Professor of Biology in the University of Western Australia, Perth, Western Australia.
1914. ‡Dakin, Mrs. University of Western Australia, Perth, Western Australia.
1898. *Dalby, W. E., M.A., B.Sc., F.R.S., M.Inst.C.E. (Pres. G, 1910), Professor of Civil and Mechanical Engineering in the City and Guilds Engineering College, Imperial College of Science and Technology, S.W. 7.
1889. *Dale, Miss Elizabeth. Garth Cottage, Oxford-road, Cambridge.
1919. §Dale, H. H. 140 Thurlow Park-road, S.E. 21.
1906. §Dale, William, F.S.A., F.G.S. The Lawn, Archer's-road, Southampton.
1907. ‡Dalgliesh, Richard, J.P., D.L. Ashfordby Place, near Melton Mowbray.

Year of Election.

1904. *Dalton, J. H. C., M.D. The Plot, Adams-road, Cambridge.
1862. ‡Danby, T. W., M.A., F.G.S. The Crouch, Seaford, Sussex.
1905. ‡Daniel, Miss A. M. 3 St. John's-terrace, Weston-super-Mare.
1901. *Daniell, G. F., B.Sc. 4 Albion-place, Maidstone.
1914. ‡Danks, A. T. 391 Bourke-street, Melbourne.
1896. §Danson, F. C. Tower-buildings, Water-street, Liverpool.
1897. ‡Darbishire, F. V., B.A., Ph.D. Dorotheenstrasse 12, Dresden 20.
1903. ‡Darbishire, Dr. Otto V. The University, Bristol.
1916. ‡Darnell, E. Town Hall, Newcastle-on-Tyne.
1905. ‡Darwin, Lady. Newnham Grange, Cambridge.
1904. *Darwin, Charles Galton. Newnham Grange, Cambridge.
1882. *Darwin, Sir Francis, M.A., M.B., LL.D., D.Sc., F.R.S., F.L.S. (President, 1908; Pres. D, 1891; Pres. K, 1904; Council, 1882–84, 1897–1901.) 10 Madingley-road, Cambridge.
1878. *Darwin, Sir Horace, K.B.E., M.A., F.R.S. The Orchard, Huntingdon-road, Cambridge.
1894. *Darwin, Major Leonard, F.R.G.S. (Pres. E, 1896; Council, 1899–1905.) 12 Egerton-place, South Kensington, S.W. 3.
1910. ‡Dauncey, Mrs. Thursby. Lady Stewert, Heath-road, Weybridge.
1916. *Davey, Miss Alice J., M.Sc. 1 Henderson road, Wandsworth Common, S.W. 18.
1880. *Davey, Henry, M.Inst.C.E. Conaways, Ewell, Surrey.
1884. ‡David, A. J., B.A., LL.B. 4 Harcourt-buildings, Temple, E.C. 4.
1914. ‡David, Professor T. W. Edgeworth, C.M.G., D.Sc., F.R.S. The University, Sydney, N.S.W.
1904. ‡Davidge, H. T., B.Sc., Professor of Electricity in the Ordnance College, Woolwich.
1913. §Davidge, W. R., A.M.Inst.C.E., Housing Commissioner for London. Wellington House, Buckingham-gate, S.W. 1.
1909. ‡Davidson, A. R. 150 Stradbrooke-place, Winnipeg, Canada.
1912. ‡Davidson, Rev. J. The Manse, Douglas, Isle of Man.
1912. ‡Davidson, John, M.A., D.Ph. Training College, Small's Wynd, Dundee.
1902. *Davidson, S. C. Seacourt, Bangor, Co. Down.
1914. ‡Davidson, W. R. 15 Third-avenue, Hove.
1887. *Davies, H. Rees. Treborth, Bangor, North Wales.
1904. §Davies, Henry N., F.G.S. 26 Lower Church-road, Weston-super-Mare.
1906. ‡Davies, S. H. Ryecroft, New Earswick, York.
1893. *Davies, Rev. T. Witton, B.A., Ph.D., D.D., Professor of Semitic Languages in University College, Bangor, North Wales.
1896. *Davies, Thomas Wilberforce, F.G.S. 41 Park-place, Cardiff.
1870. *Davis, A. S. Stanmore, Shrubbery-road Worcester.
1896. *Davis, John Henry Grant. Dolobran, Wood Green, Wednesbury.
1910. ‡*Davis, Captain John King.* 9 *Regent-street, S.W.* 1.
1905. ‡Davis, Luther. P.O. Box 898, Johannesburg.
1885. *Davis, Rev. Rudolf. 18 Alexandra-road, Gloucester.
1886. ‡Davison, Charles, D.Sc. 16 Manor-road, Birmingham.
1912. ‡Dawkins, Miss Ella Boyd. Fallowfield House, Fallowfield, Manchester.
1864. ‡Dawkins, Sir W. Boyd, D.Sc., F.R.S., F.S.A., F.G.S. (Pres. C, 1888; Council, 1882–88.) Fallowfield House, Fallowfield, Manchester.
1885. *Dawson, Lieut.-Colonel H. P., R.A. Hurtlington Hall, Burnsall, Skipton-in-Craven.
1901. *Dawson, P. The Acre, Maryhill, Glasgow.
1905. ‡Dawson, Mrs. The Acre, Maryhill, Glasgow.

Year of Election.

1912. *Dawson, Shepherd, M.A., B.Sc. Drumchapel, near Glasgow.
1906. ‡Dawson, William Clarke. Whitefriargate, Hull.
1859. *Dawson, Captain W. G. Abbots Morton, near Worcester.
1900. ‡Deacon, M. Chase Cliffe, Whatstandwell, near Matlock.
1909. §Dean, George, F.R.G.S. 14 Evelyn-mansions, Queen's Club-gardens, W. 14.
1915. ‡Dean, H. R. Pathological Department, The University, Manchester.
1901. *Deasy, Captain H. H. P. Cavalry Club, 127 Piccadilly, W. 1.
1914. ‡Debenham, Frank. Caius College, Cambridge.
1893. *Deeley, R. M., M.Inst.C.E., F.G.S. Abbeyfield, Salisbury-avenue, Harpenden, Herts.
1911. ‡Delahunt, C. G. The Municipal College, Portsmouth.
1878. ‡Delany, Very Rev. William, LL.D. University College, Dublin.
1915. ‡Delepiné, Sheridan. Public Health Laboratory, York-place, Manchester.
1908. *Delf, Miss E. M. 96 Underhill-road, S.E. 22.
1914. ‡Delprat, G. D. Equitable-building, Collins-street, Melbourne.
1902. *Dendy, Arthur, D.Sc., F.R.S., F.L.S. (Pres. D, 1914; Council, 1912–), Professor of Zoology in King's College, London, W.C. 2.
1914. ‡Dendy, Miss. Vale Lodge, Hampstead, N.W. 3.
1913. *Denman, Thomas Hercy. 17 Churchgate, Retford, Nottinghamshire.
1908. ‡Dennehy, W. F. 23 Leeson-park, Dublin.
1889. ‡Denny, Alfred, M.Sc., F.L.S., Professor of Zoology in the University of Sheffield. Cliffside, Ranmoor-crescent, Sheffield.
1909. §Dent, Edward, M.A. 2 Carlos-place, W. 1.
1874. *Derham, Walter, M.A., LL.M., F.G.S. Junior Carlton Club, Pall Mall, S.W. 1.
1907. *Desch, Cecil H., D.Sc., Ph.D. Professor of Metallurgy in the University of Sheffield.
1919. §Devine, Alexander. Northwood Park, Winchester.
1868. *Dewar, Sir James, M.A., LL.D., D.Sc., F.R.S., F.R.S.E., V.P.C.S., Fullerian Professor of Chemistry in the Royal Institution, London, and Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge. (President, 1902; Pres. B, 1879; Council, 1883–88.) 1 Scroope-terrace, Cambridge.
1881. ‡Dewar, Lady. 1 Scroope-terrace, Cambridge.
1919. §D'Eyncourt, Sir E. H. T., K.C.B. The Admiralty, Great George-street, S.W. 1.
1889. ‡Dickinson, A. H. 52 Dean-street, Newcastle-on-Tyne.
1914. ‡Dickinson, Miss Desiree. Menzies' Hotel, Melbourne.
1916. ‡Dickinson, Miss M. Eastern House, 159 Marine-parade, Brighton.
1904. ‡Dickson, Right Hon. Charles Scott, K.C., LL.D., M.P. Carlton Club, Pall Mall, S.W. 1.
1881. ‡Dickson, Edmund, M.A., F.G.S. Claughton House, Garstang, R.S.O., Lancashire.
1887. §Dickson, H. N., C.B.E., D.Sc., F.R.S.E., F.R.G.S. (Pres. E, 1913; Council 1915–19), Muirhead's Guide-books, 4a, Bloomsbury-square, W.C. 2.
1902. §Dickson, James D. Hamilton, M.A., F.R.S.E. 6 Cranmer-road, Cambridge.
1913. *Dickson, T. W. 60 Jeffrey's-road, Clapham, S.W.
1908. ‡Dines, J. S. Pyrton Hill, Watlington.
1901. §Dines, W. H., B.A., F.R.S. Benson, Wallingford, Berks.

Year of Election.

1905. §Dixey, F. A., M.A., M.D., F.R.S. (Pres. D, 1919; Council, 1913– .) Wadham College, Oxford.
1899. *Dixon, A. C., D.Sc., F.R.S., Professor of Mathematics in Queen's University, Belfast. Hurstwood, Malone Park, Belfast.
1874. *Dixon, A. E., M.D., Professor of Chemistry in University College, Cork.
1900. ‡Dixon, A. Francis, Sc.D., Professor of Anatomy in the University of Dublin.
1915. *Dixon, Miss Annie, F.R.M.S. Broadwater, 43 Pine-road, Didsbury.
1905. ‡Dixon, Miss E. K. Fern Bank, St. Bees, Cumberland.
1908. ‡Dixon, Edward K., M.E., M.Inst.C.E. Castlebar, Co. Mayo.
1888. ‡Dixon, Edward T. Racketts, Hythe, Hampshire.
1908. *Dixon, Ernest, B.Sc., F.G.S. The Museum, Jermyn-street, S.W. 1.
1900. *Dixon, Lieut.-Colonel George, M.A. Fern Bank, St. Bees, Cumberland.
1879. *Dixon, Harold B., C.B.E., M.A., F.R.S., F.C.S. (Pres. B. 1894; Council, 1913–17), Professor of Chemistry in the Victoria University, Manchester.
1914. ‡Dixon, Mrs. H. B., Beechey House, Wilbraham-road, Fallowfield, Manchester.
1902. ‡Dixon, Henry H., Sc.D., F.R.S., Professor of Botany in the University of Dublin. Clevedon, Temple-road, Dublin.
1913. ‡Dixon, S. M., M.A., M.Inst.C.E., Professor of Civil Engineering in the Imperial College of Science and Technology, London, S.W. 7.
1908. *Dixon, Walter, F.R.M.S. Derwent, 30 Kelvinside-gardens, Glasgow.
1907. *Dixon, Professor Walter E., F.R.S. The Museums, Cambridge.
1914. ‡Dixon, Mrs. W. E. The Grove, Whittlesford, Cambridge.
1902. ‡Dixon, W. V. Department of Agriculture, Dublin.
1896. §Dixon-Nuttall, F. R. Ingleholme, Eccleston Park, Prescot.
1890. ‡Dobbie, Sir James J., D.Sc., LL.D., F.R.S., Principal of the Government Laboratories, 13 Clement's Inn-passage, W.C. 2.
1885. §Dobbin, Leonard, Ph.D. The University, Edinburgh.
1902. ‡Dobbs, F. W., M.A. Eton College, Windsor.
1914. ‡Docker, His Honour Judge E. B., M.A. Mostyn, Elizabeth Bay, Sydney, N.S.W.
1917. *Docker, Frank Dudley, C.B. The Gables, Kenilworth.
1908. ‡Dodd, Hon. Mr. Justice. 26 Fitzwilliam-square, Dublin.
1876. ‡Dodds, J. M. St. Peter's College, Cambridge.
1912. ‡Don, A. W. R. The Lodge, Broughty Ferry, Forfarshire.
1919. §Don, John, M.A., B.Sc. Gardenrose, Maybole.
1904. ‡Doncaster, Leonard, M.A., F.R.S., Denby Professor of Zoology in the University of Liverpool.
1896. ‡Donnan, F. E. Ardenmore-terrace, Holywood, Ireland.
1901. ‡Donnan, F. G., C.B.E., M.A., Ph.D., F.R.S., Professor of Chemistry in University College, Gower-street, W.C. 1.
1915. §Doodson, Arthur T., D.Sc. The Tidal Institute, The University, Liverpool.
1905. §Dornan, Rev. S. S. P.O. Box 106, Bulawayo, South Rhodesia, South Africa.
1863. *Doughty, Charles Montagu. 26 Grange-road, Eastbourne.
1909. ‡Douglas, A. J., M.D. City Health Department, Winnipeg, Canada.
1909. *Douglas, James. 99 John-street, New York, U.S.A.
1912. ‡Doune, Lord. Kinfauns Castle, Perth.
1884. *Dowling, D. J. Sycamore, Clive-avenue, Hastings.
1881. *Dowson, J. Emerson, M.Inst.C.E. Landhurst Wood, Hartfield, Sussex.

Year of Election.

1913. ‡*Dracopoli, J. N. Pollard's Wood Grange, Chalfont St. Giles, Buckinghamshire.*
1892. *Dreghorn, David, J.P. Greenwood, Pollokshields, Glasgow.
1912. §Drever, James, M.A., B.Sc., D.Phil. Combe Department of Psychology, The University, Edinburgh.
1905. ‡Drew, H. W., M.B., M.R.C.S. Mocollup Castle, Ballyduff, S.O., Co. Waterford.
1906. *Drew, Joseph Webster, M.A., LL.M. Hatherley Court, Cheltenham.
1906. *Drew, Mrs. Hatherley Court, Cheltenham.
1908. ‡Droop, J. P. 11 Cleveland-gardens, Hyde Park, W. 2.
1893. §Druce, G. Claridge, M.A., F.L.S. (Local Sec. 1894.) Yardley Lodge, 9 Crick-road, Oxford.
1909. *Drugman, Julien, Ph.D., M.Sc. 117 Rue Gachard, Brussels.
1918. §Drummond, Miss Isabella M. 31 Ravenscroft-avenue, Golder's Green, N.W. 5.
1889. ‡Drummond, Dr. David. 6 Saville-place, Newcastle-on-Tyne.
1907. ‡Drysdale, Charles V., D.Sc. Queen Anne's-chambers, S.W. 1.
1892. ‡Du Bois, Professor Dr. H. Herwarthstrasse 4, Berlin, N.W.
1919. *Duchesne, M. C. Farnham Common, Slough, Bucks.
1856. *Ducie, The Right Hon. Henry John Reynolds Moreton, Earl of, G.C.V.O., F.R.S., F.G.S. 16 Portman-square, W. 1.
1920. MR Duckham, Sir A. McD., K.C.B., M.Inst.C.E. 231 Strand, W.C. 2.
1870. ‡Duckworth, Henry, F.L.S., F.G.S. 7 Grey Friars, Chester.
1900. *Duckworth, W. L. H., M.D., Sc.D. Jesus College, Cambridge.
1914. ‡Duffield, D. Walter. 13 Cowra-chambers, Grenfell-street, Adelaide, South Australia.
1912. §Duffield, Francis A., M.B. The University, Liverpool.
1904. *Duffield, Professor W. Geoffrey, D.Sc. University College, Reading.
1890. ‡Dufton, S. F. Trinity College, Cambridge.
1899. *Dugdale-Bradley, J. W., M.Inst.C.E. Westminster City Hall, Charing Cross-road, W.C. 2.
1911. ‡*Dummer, John.* 85 *Cottage-grove, Southsea.*
1914. ‡Dun, W. S. Mines Department, Sydney, N.S.W.
1909. ‡Duncan, D. M., M.A. 83 Spence-street, Winnipeg, Canada.
1916. §Dunkerley, G. D. 124 Mildred-avenue, Watford.
1916. ‡Dunn, Dr. J. T. Fellside, Low Fell, Gateshead.
1918. *Dunn, Walter, Secretary Institution of Gas Engineers. 39 Victoria-street, S.W. 1.
1876. ‡Dunnachie, James. 48 West Regent-street, Glasgow.
1916. ‡Dunning, James E. 3 Lombard-street, E.C. 3.
1884. §Dunnington, Professor F. P. University of Virginia, Charlottesville, Virginia, U.S.A.
1893. *Dunstan, M. J. R., O.B.E., Principal of the South-Eastern Agricultural College, Wye, Kent.
1891. ‡Dunstan, Mrs. South-Eastern Agricultural College, Wye, Kent.
1885. *Dunstan, Wyndham R., C.M.G., M.A., LL.D., F.R.S., F.C.S. (Pres. B, 1906; Council, 1905–08), Director of the Imperial Institute, S.W. 7.
1911. ‡Dupree, Colonel Sir W. T. Craneswater, Southsea.
1914. §Du Toit, A. L., D.Sc. Irrigation Department, Pretoria, South Africa.
1914. ‡Du Toit, Mrs. Irrigation Department, Pretoria, South Africa.
1905. §Dutton, C. L. O'Brien. High Commissioner's Office, Pretoria.
1910. ‡Dutton, F. V., B.Sc. County Agricultural Laboratories, Richmond-road, Exeter.

Year of Election.

1895. *Dwerryhouse, Arthur R., T.D., D.Sc., F.G.S. St. Michan's, Deramore Park South, Belfast.
1911. ‡Dye, Charles. Woodcrofts, London-road, Portsmouth.
1895. ‡Dymond, Thomas S., F.C.S. Savile Club, Piccadilly, W 1.
1905. *Dyson, Sir F. W., M.A., LL.D., F.R.S. (Pres. A, 1915; Council, 1905–11, 1914–), Astronomer Royal. Royal Observatory, Greenwich, S.E. 10.
1910. ‡*Dyson, W. H. Maltby Colliery, near Rotherham, Yorkshire.*

1912. ‡Earland, Arthur, F.R.M.S. 34 Granville-road, Watford.
1919. *East, Charles H., M.D. St. Clare, Great Malvern.
1899. ‡East, W. H. Municipal School of Art, Science, and Technology, Dover.
1909. *Easterbrook, C. C., M.A., M.D. Crichton Royal Institution, Dumfries.
1893. *Ebbs, Alfred B. Tuborg, Plaistow-lane, Bromley, Kent.
1906. *Ebbs, Mrs. A. B. Tuborg, Plaistow-lane, Bromley, Kent.
1909. ‡Eccles, J. R. Gresham's School, Holt, Norfolk.
1903. *Eccles, W. H., D.Sc., Professor of Physics in the City and Guilds of London Technical College, Leonard-street, Finsbury, E.C. 2.
1908. *Eddington, A. S., M.A., M.Sc., F.R.S., Plumian Professor of Astronomy and Experimental Philosophy in the University of Cambridge. The Observatory, Cambridge.
1870. *Eddison, John Edwin, M.D., M.R.C.S. The Lodge, Adel, Leeds.
1911. *Edge, S. F. Gallops Homestead, Ditchling, Sussex.
1911. *Edgell, Miss Beatrice. Bedford College, Regent's Park, N.W. 1.
1884. *Edgell, Rev. R. Arnold, M.A. Beckley Rectory, East Sussex.
1887. §Edgeworth, F. Y., M.A., D.C.L., F.S.S. (Pres. F, 1889; Council, 1879–86, 1891–98), Professor of Political Economy in the University of Oxford. All Souls College, Oxford.
1883. ‡Edmonds, William. Wiscombe Park, Colyton, Devon.
1888. *Edmunds, Henry. Moulsecombe-place, Brighton.
1901. *Edridge-Green, F. W., C.B.E., M.D., F.R.C.S. 99 Walm-lane, Willesden Green, N.W. 2.
1914. ‡Edwards, A. F. Chemical Department, The University, Manchester.
1915. ‡Edwards, C. A. 26 Lyndhurst-road, Withington, Manchester.
1899. §Edwards, E. J., Assoc.M.Inst.C.E. 3 Spencer-road, Wandsworth, S.W. 18.
1913. §Edwards, E. J. Royal Technical College, Glasgow.
1901. ‡Eggar, W. D. Eton College, Windsor.
1909. ‡Eggertson, Arni. 120 Emily-street, Winnipeg, Canada.
1909. §Ehrenborg, G. B. 1 Dean-road, Croydon.
1907. *Elderton, W. Palin. 24 Mount Ephraim-road, Streatham, S.W. 16.
1890. ‡Elford, Percy. 115 Woodstock-road, Oxford.
1913. ‡Elkington, Herbert F. Clunes, Wentworth-road, Sutton Coldfield.
1901. *Elles, Miss Gertrude L., D.Sc. Newnham College, Cambridge.
1915. §Ellinger, Barnard, F.S.S. 28 Oxford-street, Manchester.
1904. ‡Elliot, Miss Agnes I. M. Newnham College, Cambridge.
1904. ‡Elliot, R. H. Clifton Park, Kelso, N.B.
1905. ‡Elliott, C. C., M.D. Church-square, Cape Town.
1883. *Elliott, Edwin Bailey, M.A., F.R.S., F.R.A.S., Waynflete Professor of Pure Mathematics in the University of Oxford, 4 Bardwell-road, Oxford.

Year of Election.

1912. §Elliott, Dr. W. T., F.L.S., F.Z.S. 21 Bennett's-hill, Birmingham.
1906. *Ellis, David, D.Sc., Ph.D. Royal Technical College, Glasgow.
1875. *Ellis, H. D. 6 Clinton-terrace, Budleigh Salterton.
1906. §Ellis, Herbert. The Gynsills, Groby-road, Leicester.
1891. ‡Ellis, Miss M. A. Care of Miss Rice, 11 Canterbury-road, Oxford.
1906. ‡Elmhirst, Charles E. (Local Sec. 1906.) 29 Mount-vale, York.
1910. ‡Elmhirst, Richard. Marine Biological Station, Millport.
1911. ‡Elwes, H. J., F.R.S. Colesborne Park, near Cheltenham.
1884. ‡Emery, Albert H. Stamford, Connecticut, U.S.A.
1905. ‡Epps, Mrs. Dunhurst, Petersfield, Hampshire.
1894. ‡Erskine-Murray, J., D.Sc., F.R.S.E. 4 Great Winchester-street, E.C. 2.
1914. ‡Erson, Dr. E. G. Leger. 123 Collins-street, Melbourne.
1887. *Estcourt, Charles, F.I.C. 5 Seymour-grove, Old Trafford, Manchester.
1887. *Estcourt, P. A., F.C.S., F.I.C. 5 Seymour-grove, Old Trafford, Manchester.
1911. ‡Etherton, G. Hammond. (Local Sec. 1911.) Town Hall, Portsmouth.
1897. *Evans, Lady. Care of Union of London and Smiths Bank, Berkhamsted, Herts.
1889. *Evans, A. H., M.A. 9 Harvey-road, Cambridge.
1905. ‡Evans, Mrs. A. H. 9 Harvey-road, Cambridge.
1870. *Evans, Sir Arthur John, M.A., LL.D., F.R.S., F.S.A. (President, 1916-19; Pres. H, 1896.) Youlbury, Berks, near Oxford.
1919. §Evans, C. Lovatt, D.Sc. Lister Institute, Chelsea-gardens, S.W.
1908. ‡Evans, Rev. Henry, D.D., Commissioner of National Education, Ireland. Blackrock, Co. Dublin.
1887. *Evans, Mrs. Isabel. Cranford, East Beach, Lytham.
1905. ‡Evans, Ivor H. N. 9 Harvey-road, Cambridge.
1913. ‡Evans, J. Jameson. 41 Newhall-street, Birmingham.
1910. *Evans, John W., D.Sc., LL.B., F.R.S., F.G.S. (Pres. C, 1919.) Imperial College, of Science and Technology, S.W. 7.
1905. ‡Evans, R. O. Ll. Broom Hall, Chwilog, R.S.O., Carnarvonshire.
1910. ‡Evans, T. J. The University, Sheffield.
1865. *Evans, William. The Spring, Kenilworth.
1909. ‡Evans, W. Sanford, M.A. (Local Sec. 1909.) 43 Edmonton-street, Winnipeg.
1902. *Everett, Percy W. Oaklands, Elstree, Hertfordshire.
1883. ‡Eves, Miss Florence. Uxbridge.
1914. ‡Ewart, Professor A. J., D.Sc. The University, Melbourne.
1881. ‡Ewart, J. Cossar, M.D., F.R.S. (Pres. D, 1901), Professor of Natural History in the University of Edinburgh.
1913. *Ewen, J. T. 104 King's-gate, Aberdeen.
1913. *Ewen, Mrs. J. T. 104 King's-gate, Aberdeen.
1876. *Ewing, Sir J. Alfred, K.C.B., M.A., LL.D., F.R.S., F.R.S.E., M.Inst.C.E. (Pres. G, 1906), Principal of the University of Edinburgh. 16 Moray-place, Edinburgh.
1914. §Ewing, Mrs. Peter. 6 Glenan-gardens, Helensburgh, Glasgow.
1884. *Eyerman, John, F.Z.S. Oakhurst, Easton, Pennsylvania, U.S.A.
1912. ‡Eyre, Dr. J. Vargas. South-Eastern Agricultural College, Wye, Kent.

1906. *Faber, Sir George D., C.B., M.P. 14 Grosvenor-square, W. 1.
1901. *Fairgrieve, M. McCallum 37 Queen's-crescent, Edinburgh.

Year of Election

1919. §Fairweather, Miss N. M. Eldon Cottage, Seabourne-road, Bournemouth.
1910. ‡Falconer, J. D., M.A., D.Sc. Care of Postmaster, Naraguta, Northern Nigeria.
1908. ‡Falconer, Robert A., M.A. 23 Fitzwilliam-place, Dublin.
1896. §Falk, Herman John, M.A. Thorshill, West Kirby, Cheshire.
1902. §Fallaize, E. N., B.A. Vinchelez, Chase Court-gardens, Windmill-hill, Enfield.
1907. *Fantham, H. B., M.A., D.Sc., Professor of Zoology in the School of Mines and Technology, University of South Africa, Johannesburg.
1902. ‡Faren, William. 11 Mount Charles, Belfast.
1892. *Farmer, Professor J. Bretland, M.A., F.R.S., F.L.S. (Pres. K., 1907; Council, 1912–14). South Park, Gerrard's Cross.
1905. ‡Farrar, Edward. P.O. Box 1242, Johannesburg.
1919. §Farrow, E. P., M.A., D.Sc. Limehurst, Spalding, Lincolnshire.
1913. ‡Farrow, F. D. Rhodes University College, Grahamstown, South Africa.
1913. *Fawcett, C. B. The University, Leeds.
1890. *Fawcett, F. B. 1 Rockleaze-avenue, Sneyd Park, Bristol.
1906. §Fawcett, Henry Hargreave. Thorncombe, near Chard, Somerset.
1900. ‡Fawcett, J. E., J.P. (Local Sec. 1900.) Low Royd, Apperley Bridge, Bradford.
1902. *Fawsitt, C. E., Ph.D., Professor of Chemistry in the University of Sydney, New South Wales. Temporary—Coneypark, Bridge of Allan, Stirlingshire.
1911. *Fay, Mrs. A. Q. Chedworth, Rustat-road, Cambridge.
1909. *Fay, Charles Ryle, M.A. Christ's College, Cambridge.
1901. *Fearnsides, W. G., M.A., F.G.S., Sorby Professor of Geology in the University of Sheffield. 10 Silver Birch-avenue, Fulwood, Sheffield.
1910. *Fearnsides, Mrs. 10 Silver Birch-avenue, Fulwood, Sheffield.
1905. ‡Feilden, Colonel H. W., C.B., F.R.G.S., F.G.S. Burwash, Sussex.
1900. *Fennell, William John. 2 Wellington-place, Belfast.
1904. ‡Fenton, H. J. H., M.A., Sc.D., F.R.S. 19 Brookside, Cambridge.
1919. §Fenwick, Dr. E. 43 Porchester-road, Bournemouth.
1914. ‡Ferguson, E. R. Gordon-street, Footscray, Victoria, Australia.
1901. ‡Ferguson, R. W. 16 Linden-road, Bournville, near Birmingham.
1863. *Fernie, John. Box No. 2, Hutchinson, Kansas, U.S.A.
1910. *Ferranti, S. Z. de, M.Inst.C.E. Grindleford, near Sheffield.
1905. *Ferrar, H. T., M.A., F.G.S. Care of A. Anderson, Esq., St. Martin's, Christchurch, New Zealand.
1914. ‡Ferrar, Mrs. Care of A. Anderson, Esq., St. Martin's, Christchurch, New Zealand.
1873. ‡Ferrier, Sir David, M.A., M.D., LL.D., F.R.S. 34 Cavendish-square, W. 1.
1909. ‡Fetherstonhaugh, Professor Edward P., B.Sc. 119 Betourney-street, Winnipeg, Canada.
1919. §Ffennell, E. B., M.D. West Heath, Southbourne, Bournemouth.
1915. ‡Field, A. B. Kingslea, Marple, near Stockport.
1913. ‡Field, Miss E. E. Hollywood, Egham Hill, Surrey.
1897. ‡Field, George Wilton, Ph.D. Bureau of Biological Survey, Washington, U.S.A.
1919. §Field, L., F.C.S. Northampton Institute, E.C. 1.
1907. *Fields, Professor J. C., F.R.S. The University, Toronto, Canada.

Year of Election.

1906. §Filon, L. N. G., D.Sc., F.R.S., Professor of Applied Mathematics in the University of London. 11 Nottingham-road, Croydon.

1905. §Findlay, Alexander, M.A., Ph.D., D.Sc., Professor of Chemistry in the University of Aberdeen.

1904. *Findlay, J. J., Ph.D., Professor of Education in the Victoria University, Manchester. Ruperra, Victoria Park, Manchester.

1912. ‡Finlayson, Daniel, F.L.S. Seed Testing Laboratory, Wood Green, N.

1902. ‡Finnegan, J., M.A., B.Sc. Kelvin House, Botanic-avenue, Belfast.

1909. ‡Fisher, James, K.C. 216 Portage-avenue, Winnipeg, Canada.

1875. *Fisher, W. W., M.A., F.C.S. 5 St. Margaret's-road, Oxford.

1887. *Fison, Alfred H., D.Sc. 47 Dartmouth-road, Willesden Green, N.W. 2.

1871. *Fison, Sir Frederick W., Bart., M.A., F.C.S. Boarzell, Hurst Green, Sussex.

1885. *Fitzgerald, Professor Maurice, B.A. (Local Sec. 1902.) Fairholme, Monkstown, Co. Dublin.

1894. ‡Fitzmaurice, Sir Maurice, C.M.G., F.R.S., M.Inst.C.E. London County Council, Spring-gardens, S.W. 1.

1888. *Fitzpatrick, Rev. Thomas C., President of Queens' College, Cambridge.

1904. ‡Flather, J. H., M.A. Camden House, 90 Hills-road, Cambridge.

1915. ‡Fleck, Alexander. Blenheim-avenue, Stepps, near Glasgow.

1915. *Fleming, Arthur P. M. West Gables, Hale-road, Hale, Cheshire.

1913. ‡Fleming, Professor J. A., D.Sc., F.R.S. University College, Gower-street, W.C. 1.

1892. ‡Fletcher, George, F.G.S. Mona, Shankhill, Co. Dublin.

1888. *Fletcher, Sir Lazarus, M.A., Ph.D., F.R.S., F.G.S., F.C.S. (Pres. C, 1894.) The White House, Ravenstone-dale, viâ Penwith.

1908. *Fletcher, W. H. B. Aldwick Manor, Bognor, Sussex.

1901. ‡Flett, J. S., O.B.E., M.A., D.Sc., F.R.S., F.R.S.E. Geological Survey Office, 33 George-square, Edinburgh.

1906. *Fleure, H. J., D.Sc., Professor of Zoology and Geology in University College, Aberystwyth.

1905. *Flint, Rev. W., D.D. Houses of Parliament, Cape Town.

1913. *Florence, P. Sargant, B.A. Caius College, Cambridge.

1889. ‡Flower, Lady. 26 Stanhope-gardens, S.W. 7.

1890. *Flux, A. W., M.A. Board of Trade, Gwydyr House, Whitehall, S.W. 1.

1914. ‡Flynn, Professor T. Thomson. University of Tasmania, Hobart.

1877. ‡Foale, William. The Croft, Madeira Park, Tunbridge Wells.

1911. ‡Foran, Charles. 72 Elm-grove, Southsea.

1906. §Forbes, Charles Mansfeldt. 14 New-street, York.

1914. ‡Forbes, E. J. P.O. Box 1604, Sydney, N.S.W.

1914. ‡Forbes, Mrs. E. J. P.O. Box 1604, Sydney, N.S.W.

1873. *Forbes, George, M.A., F.R.S., F.R.S.E., M.Inst.C.E. 11 Little College-street, Westminster, S.W. 1.

1883. ‡Forbes, Henry O., LL.D., F.Z.S. Redcliffe, Beaconsfield, Bucks.

1905. ‡Forbes, Lieut.-Colonel W. Lachlan. Army and Navy Club, Pall Mall, S.W. 1.

1919. §Forder, B. C. The Down Wood, Blandford, Dorset.

Year of Election.

1875. *Fordham, Sir George. Odsey, Ashwell, Baldock, Herts.
1909. ‡Forget, The Hon. A. E. Regina, Saskatchewan, Canada.
1915. §Forrester, Robert B. Marischal College, Aberdeen.
1902. *Forster, M. O., Ph.D., D.Sc., F.R.S. Queen Anne's-mansions, S.W. 1.
1883. ‡Forsyth, Professor A. R., M.A., D.Sc., F.R.S. (Pres. A, 1897, 1905; Council, 1907–09.) Imperial College of Science and Technology, South Kensington, S.W. 7.
1911. ‡Foster, F. G. Ivydale, London-road, Portsmouth.
1901. ‡Foster, Sir T. Gregory, Ph.D., Provost of University College, London. University College, Gower-street, W.C. 1.
1903. ‡Fourcade, H. G. P.O., Storms River, Humansdorp, Cape Colony.
1905. §Fowlds, Hiram. 65 Devonshire-street, Keighley, Yorkshire.
1909. ‡Fowlds, Mrs. 65 Devonshire-street, Keighley, Yorkshire.
1912. ‡Fowler, A., F.R.S., Professor of Astrophysics in the Imperial College of Science and Technology, S.W. 19 Rusthall-avenue, Bedford Park, W. 4.
1919. §Fowler, Dr. Frank. 29 Poole-road, Bournemouth.
1883. ‡Fox, Sir Charles Douglas, M.Inst.C.E. (Pres. G, 1896.) Cross Keys House, 56 Moorgate-street, E.C. 2.
1904. *Fox, Charles J. J., B.Sc., Ph.D., Professor of Chemistry in the Presidency College of Science, Poona, India.
1904. §Fox, F. Douglas, M.A., M.Inst.C.E. 19 The Square, Kensington, W.
1905. ‡Fox, Mrs. F. Douglas. 19 The Square, Kensington, W.
1883. ‡Fox, Howard, F.G.S. Rosehill, Falmouth.
1900. *Fox, Thomas. Old Way House, Wellington, Somerset.
1909. *Fox, Wilson Lloyd. Carmino, Falmouth.
1908. ‡Foxley, Miss Barbara, M.A., Professor of Education in University College, Cardiff.
1881. *Foxwell, Herbert S., M.A., F.S.S. (Council, 1894–97), Professor of Political Economy in University College, London. St. John's College, Cambridge.
1887. *Frankland, Percy F., C.B.E., Ph.D., B.Sc., F.R.S. (Pres. B. 1901.) House of Letterawe, Loch Awe, Argyllshire.
1913. §Franklin, Cyril H. H. Milford House, Canon-street, Shrewsbury.
1911. ‡Fraser, Dr. A. Mearns. (Local Sec. 1911.) Town Hall, Portsmouth.
1911. ‡Fraser, Mrs. A. Mearns. Cheyne Lodge, St. Ronan's-road, Portsmouth.
1911. ‡Freeman, Oliver, B.Sc. The Municipal College, Portsmouth.
1916. ‡Freire-Marreco, Miss Barbara. Peter's Croft, Woodham-road, Woking.
1906. §French, Fleet-Surgeon A. M. Langley, Beaufort-road, Kingston-on-Thames.
1909. ‡French, Mrs. Harriet A. Suite E, Gline's-block, Portage-avenue, Winnipeg, Canada.
1912. §French, Mrs. Harvey. Hambledon Lodge, Childe Okeford, Blandford.
1905. ‡French, Sir Somerset R., K.C.M.G. 100 Victoria-street, S.W. 1.
1886. ‡Freshfield, Douglas W., F.R.G.S. (Pres. E, 1904.) 1 Airlie-gardens, Campden Hill, W. 8.
1887. *Fries, Harold H., Ph.D. 92 Reade-street, New York, U.S.A.
1906. ‡Fritsch, Dr. F. E. 77 Chatsworth-road, Brondesbury, N.W. 2.
1912. ‡Frodsham, Miss Margaret, B.Sc. The College School, 34 Cathedral-road, Cardiff.

Year of Election.

1892. *Frost, Edmund, M.D. Chesterfield-road, Eastbourne.
1868. §Frost, Edward P., D.L., J.P. West Wratting Hall, Cambridgeshire
1911. ‡Frost, M. E. P. H.M. Dockyard, Portsmouth.
1887. *Frost, Robert, B.Sc. 55 Kensington-court, W. 8.
1908. ‡Fry, M. W. J., M.A. 39 Trinity College, Dublin.
1905. *Fry, Sir William, J.P., F.R.G.S. Wilton House, Merrion-road, Dublin.
1898. ‡Fryer, Alfred C., Ph.D. 13 Eaton-crescent, Clifton, Bristol.
1872. *Fuller, Rev. A. 7 Sydenham-hill, Sydenham, S.E. 26.
1912. ‡Fulton, Angus R., B.Sc. University College, Dundee.
1913. *Fyson, Philip Furley, B.A., F.L.S. Elmley Lovett, Droitwich.

1910. ‡Gadow, H. F., Ph.D., F.R.S. (Pres. D, 1913.) Zoological Laboratory, Cambridge.
1863. *Gainsford, W. D. Skendleby Hall, Spilsby.
1906. ‡Gajjar, Professor T. K., M.A., B.Sc., F.C.S., Techno-Chemical Laboratory, The Lines, Surat.
1885. *Gallaway, Alexander. Dirgarve, Aberfeldy, N.B.
1875. ‡Galloway, W. Cardiff.
1887. *Galloway, W. J. The Cottage, Seymour-grove, Old Trafford, Manchester.
1905. *Galpin, Ernest E. Naboomspruit, Transvaal.
1913. ‡Gamble, F. W., D.Sc., F.R.S. (Local Sec., 1913), Professor of Zoology and Comparative Anatomy in the University of Birmingham. Scarsfields House, Alvechurch, Worcestershire.
1888. *Gamble, J. Sykes, C.I.E., M.A., F.R.S., F.L.S. Highfield, East Liss, Hants.
1911. ‡Garbett, Rev. C. F., M.A. The Vicarage, Fratton-road, Portsmouth.
1899. *Garcke, E. Ditton House, near Maidenhead.
1898. ‡Garde, Rev. C. L. Skenfrith Vicarage, near Monmouth.
1911. ‡Gardiner, C. I., M.A., F.G.S. 6 Paragon-parade, Cheltenham.
1912. §Gardiner, F. A., F.L.S. 12 The Ridgeway, Golder's Green, N.W. 4.
1905. ‡Gardiner, J. H. 59 Wroughton-road, Balham, S.W. 11.
1900. ‡Gardiner, J. Stanley, M.A., F.R.S., Professor of Zoology and Comparative Anatomy in the University of Cambridge, Zoological Laboratory, Cambridge.
1887. ‡Gardiner, Walter, M.A., D.Sc., F.R.S. St. Awdreys, Hills-road, Cambridge.
1882. *Gardner, H. Dent, F.R.G.S. Fairmead, 46 The Goffs, Eastbourne.
1912. §Gardner, Willoughby, F.L.S. Y Berlfa, Deganwy, North Wales.
1912. §Garfitt, G. A. Cartledge Hall, Holmesfield, near Sheffield.
1915. §Garforth, Sir William, M.Inst.C.E. Snydale Hall, near Pontefract.
1913. *Garnett, Principal J. C. Maxwell, M.A. (Local Sec. 1915.) College of Technology, Manchester.
1905. ‡Garnett, Mrs. Maxwell, F.Z.S. Westfield, Victoria Park, Manchester.
1887. *Garnett, Jeremiah. The Grange, Bromley Cross, near Bolton, Lancashire.
1882. ‡Garnett, William, D.C.L. London County Council, Victoria Embankment, W.C. 2.
1883. ‡Garson, J. G., M.D. (Assist. Gen. Sec. 1902–04.) The War Hospital, Ewell.

Year of Election.

1903. ‡Garstang, A. H. 64 Torridge-road, Thornton Heath.
1903. *Garstang, T. James, M.A. Dunhill House, Petersfield, Hampshire.
1894. *Garstang, Walter, M.A., D.Sc., F.Z.S., Professor of Zoology in the University of Leeds.
1874. *Garstin, John Ribton, M.A., M.R.I.A., F.S.A. Braganstown, Castlebellingham, Ireland.
1889. ‡Garwood, E. J., M.A., F.R.S., F.G.S. (Pres. C, 1913), Professor of Geology in the University of London. University College, Gower-street, W.C. 1.
1905. ‡Gaskell, Miss C. J. The Uplands, Great Shelford, Cambridge.
1905. ‡Gaskell, Miss M. A. The Uplands, Great Shelford, Cambridge.
1906. ‡Gaster, Leon. 32 Victoria-street, S.W.
1913. *Gates, R. R., Ph.D., F.L.S. University of London Club, 21 Gower-street, W.C. 1.
1911. ‡Gates, W. 'Evening News' Office, Portsmouth.
1916. ‡Gaunt, J. B. Rutherford College, Newcastle-on-Tyne.
1912. §Gavin, W., M.A. Coombe House, Coombe, Oxon.
1905. *Gearon, Miss Susan. 26 Oakdale-road, Streatham, S.W. 16.
1885. ‡Geddes, Professor Patrick, F.R.S.E. Outlook Tower, Edinburgh.
1887. ‡Gee, W. W. Haldane. Oak Lea, Whalley-avenue, Sale.
1867. ‡Geikie, Sir Archibald, O.M., K.C.B., LL.D., D.Sc., F.R.S., F.R.S.E., F.G.S. (President, 1892; Pres. C, 1867, 1871, 1899; Council, 1888–1891.) Shepherd's Down, Haslemere, Surrey.
1913. §Geldart, Miss Alice M. 2 Cotman-road, Norwich.
1898. *Gemmill, James, F., M.A., M.D., Professor of Natural History in the University of Dundee.
1882. *Genese, R. W., M.A., Professor of Mathematics in University College, Aberystwyth.
1905. ‡Gentleman, Miss A. A. 9 Abercromby-place, Stirling.
1919. §George, A. D. Chewton Lodge, Highcliffe, Christchurch, Bournemouth.
1912. *George, H. Trevelyan, M.A., M.R.C.S., L.R.C.P. 33 Ampthill-square, N.W. 1.
1902. *Gepp, Antony, M.A., F.L.S. British Museum (Natural History), Cromwell-road, S.W. 7.
1899. *Gepp, Mrs. A. British Museum (Natural History), Cromwell-road, S.W. 7.
1884. *Gerrans, Henry T., M.A. 20 St. John-street, Oxford.
1917. ‡Gibbons, A. J. F. Montpellier, Cobo, Câtel, Guernsey.
1909. ‡Gibbons, W. M., M.A. (Local Sec. 1910.) The University, Sheffield.
1905. ‡Gibbs, Miss Lilian S., F.L.S. 22 South-street, Thurloe-square, S.W. 7.
1912. ‡Gibson, A. H., D.Sc., Professor of Engineering in University College, Dundee.
1916. §Gibson, Alfred Herbert. Presville, Kent-road, Harrogate.
1914. ‡Gibson, A. J., Ph.D. Central Sugar Mills, Brisbane, Australia.
1916. *Gibson, Professor C. S., O.B.E. The Egyptian Government School of Medicine, Cairo, Egypt.
1915. §Gibson, Charles R. Lynton, Mansewood, Pollokshaws, Glasgow.
1901. §Gibson, Professor George A., M.A. 10 The University, Glasgow.
1912. ‡*Gibson, G. E., Ph.D., B.Sc.* 16 *Woodhall-terrace, Juniper Green.*
1916. ‡Gibson, John E. 8 The Terrace, Riding Mill.
1912. *Gibson, Miss Mary H., M.A., Ph.D. Cheshire County Training College, Crewe.

Year of Election.

1896. ‡Gibson, R. J. Harvey, M.A., F.R.S.E., Professor of Botany in the University of Liverpool.
1889. *Gibson, T. G. Lesbury House, Lesbury, R.S.O., Northumberland.
1893. ‡Gibson, Walcot, F.G.S. 28 Jermyn-street, S.W. 1.
1898. *Gifford, J. William, F.R.A.S. Oaklands, Chard.
1883. ‡Gilbert, Lady. Park View, Englefield Green, Surrey.
1884. *Gilbert, Philip H. 63 Tupper-street, Montreal, Canada.
1916. ‡Gilchrist, Douglas A., M.Sc., Professor of Agriculture in Armstrong College, Newcastle-on-Tyne.
1895. ‡Gilchrist, J. D. F., M.A., Ph.D., B.Sc., F.L.S. Marine Biologist's Office, Department of Agriculture, Cape Town.
1896. *Gilchrist, Percy C., F.R.S., M.Inst.C.E. Reform Club, Pall Mall, S.W. 1.
1911. ‡Gill, Rev. H. V., S.J. Milltown Park, Clonskea, Co. Dublin.
1902. ‡Gill, James F. 72 Strand-road, Bootle, Liverpool.
1908. ‡Gill, T. P. Department of Agriculture and Technical Instruction for Ireland, Dublin.
1913. *Gillett, Joseph A., B.A. Woodgreen, Banbury.
1919. §Gilligan, Albert, D.Sc., F.G.S. The University, Leeds.
1913. ‡*Gillmor, R. E.* 57 *Victoria-street, S.W.* 1.
1892. *Gilmour, Matthew A. B., F.Z.S. Saffronhall House, Windmill-road, Hamilton, N.B.
1907. ‡Gilmour, S. C. 25 Cumberland-road, Acton, W.
1913. §Gilson, R. Cary, M.A. King Edward's School, Birmingham.
1913. ‡Gimingham, C. T., F.I.C. Research Station, Long Ashton, Bristol.
1893. *Gimingham, Edward. 144 Clapton Common, E. 5.
1904. ‡Ginn, S. R., D.L. (Local Sec. 1904.) Brookfield, Trumpington-road, Cambridge.
1886. *Gisborne, Hartley, M.E.I.C. Yoxall, Rural Route No. 1—Ladysmith, British Columbia, Canada.
1883. *Gladstone, Miss. 46 Ladbroke-grove, Notting Hill, W. 11.
1871. *Glaisher, J. W. L., M.A., Sc.D., F.R.S., F.R.A.S. (Pres. A, 1890; Council, 1878–86.) Trinity College, Cambridge.
1881. *Glazebrook, Sir R. T., K.C.B., M.A., Sc.D., F.R.S. (Pres. A, 1893; Council, 1890–94, 1905–11). Coton End, 63 Grange-road, Cambridge.
1818. *Gleadow, Frederic. Brook Bank House, Malton, Yorkshire.
1919. §Glew, F. H., M.B.E. 156 Clapham-road, S.W. 9.
1915. ‡Glover, James. Lowton House, Lowton, Lancashire.
1915. §Godlee, Francis. 8 Minshull-street, Manchester.
1878. *Godlee, J. Lister. Wakes Colne Place, Essex.
1879. ‡Godwin-Austen, Lieut.-Colonel H. H., F.R.S., F.R.G.S., F.Z.S. (Pres. E, 1883.) Nore, Godalming.
1908. *Gold, Ernest, D.S.O., M.A., F.R.S. 8 Hurst Close, Bigwood-road, Hampstead Garden Suburb, N.W. 4.
1914. ‡Gold, Mrs. 8 Hurst Close, Bigwood-road, Hampstead Garden Suburb, N.W. 4.
1906. ‡Goldie, Right Hon. Sir George D. T., K.C.M.G., D.C.L., F.R.S. (Pres. E, 1906; Council, 1906–07.) Naval and Military Club, 94 Piccadilly, W. 1.
1910. ‡Golding, Captain John, D.S.O., F.I.C. University College, Reading.
1913. ‡Golding, Mrs. University College, Reading.
1890. *Gonner, E. C. K., M.A. (Pres. F, 1897, 1914), Professor of Economic Science in the University of Liverpool. Undercliff, West Kirby, Cheshire.
1909. ‡Goodair, Thomas. 303 Kennedy-street, Winnipeg, Canada.

Year of Election.

1912. §Goodman, Sydney C. N., B.A. Quentrells, Hillbury-road, Tooting Bec Common, S.W. 17.
1907. §Goodrich, E. S., M.A., F.R.S., F.L.S. 53 Banbury-road, Oxford.
1908. ‡Goodrich, Mrs., D.Sc. 53 Banbury-road, Oxford.
1884. *Goodridge, Richard E. W. P.O. Box 36, Coleraine, Minnesota, U.S.A.
1904. ‡Goodwin, Professor L. F., Ph.D. Queen's University, Kingston, Canada.
1884. ‡Goodwin, Professor W. L. Queen's University, Kingston, Ontario, Canada.
1909. ‡Gordon, Rev. Charles W. 567 Broadway, Winnipeg, Canada.
1909. ‡Gordon, J. T. 147 Hargrave-street, Winnipeg, Canada.
1909. ‡Gordon, Mrs. J. T. 147 Hargrave-street, Winnipeg, Canada.
1911. *Gordon, J. W. 113 Broadhurst-gardens, Hampstead, N.W. 6.
1871. *Gordon, Joseph Gordon, F.C.S. Queen Anne's-mansions, Westminster, S.W. 1.
1893. ‡Gordon, Mrs. M. M. Ogilvie, D.Sc. 1 Rubislaw-terrace, Aberdeen.
1910. *Gordon, Vivian. Avonside Engine Works, Fishponds, Bristol.
1912. §Gordon, W. T., D.Sc. Geological Department, King's College, Strand, W.C. 2.
1881. ‡Gough, Rev. Thomas, B.Sc. King Edward's School, Retford.
1873. ‡Goyder, Dr. D. Marley House, 88 Great Horton-road, Bradford, Yorkshire.
1908. *Grabham, G. W., M.A., F.G.S. P.O. Box 178, Khartoum, Sudan.
1886. ‡Grabham, Michael C., M.D. Madeira.
1909. ‡Grace, J. H., M.A., F.R.S. Peterhouse, Cambridge.
1909. ‡Graham, Herbert W. 329 Kennedy-street, Winnipeg, Canada.
1914. ‡Graham, Mrs. Dolland, Clonsilla, Co. Dublin.
1875. ‡Grahame, James. (Local Sec. 1876.) Care of Messrs. Grahame, Crums, & Connal, 34 West George-street, Glasgow.
1904. §Gramont, Comte Arnaud de, D.Sc., Memb. de l'Institut de France, 179 rue de l'Université, Paris.
1896. ‡Grant, Sir James, K.C.M.G. Ottawa, Canada.
1914. ‡Grant, Kerr, M.Sc., Professor of Physics in the University of Adelaide, South Australia.
1908. *Grant, Professor W. L. Upper Canada College, Toronto, Canada.
1914. ‡Grasby, W. C. Care of G. J. W. Grasby, Esq., Grenfell-street, Adelaide, South Australia.
1890. ‡Gray, Andrew, M.A., LL.D., F.R.S., F.R.S.E. (Pres. A, 1919), Professor of Natural Philosophy in the University of Glasgow.
1864. *Gray, Rev. Canon Charles. West Retford Rectory, Retford.
1919. §Gray, C. L. C. Berkeley House, Hay Hill, W. 1.
1881. ‡Gray, Edwin, LL.B. Minster-yard, York.
1903. §Gray, Ernest, M.A. 104 Tulse-hill, S.W. 2.
1904. ‡*Gray, Rev. H. B., D.D.* (*Pres. L*, 1909.) 91 *Warwick-road, Ealing, W.* 5.
1887. ‡Gray, Joseph W., F.G.S. 6 Richmond Park-crescent, Bournemouth.
1901. ‡Gray, R. Whytlaw. University College, W.C. 1.
*Gray, Colonel William. Farley Hall, near Reading.
1866. ‡Greaves, Charles Augustus, M.B., LL.B. 84 Friar-gate, Derby
1910. *Greaves, R. H. Research Dept., Royal Arsenal, Woolwich, S.E. 18.
1904. *Green, Professor A. G., M.Sc., F.R.S. Municipal School of Technology, Manchester.

Year of Election.

1904. §*Green, F. W.* 5 *Wordsworth-grove, Cambridge.*
1914. ‡Green, Heber, D.Sc. The University, Melbourne.
1906. *Green, J. A., M.A., Professor of Education in the University of Sheffield.
1909. ‡Greenfield, Joseph. P.O. Box 2935, Winnipeg, Canada.
1882. ‡Greenhill, Sir George, M.A., F.R.S. 1 Staple Inn, W.C. 1.
1905. ‡Greenhill, William. 6A George-street, Edinburgh.
1915. ‡Greenhow, J. H. 46 Princess-street, Manchester.
1913. *Greenland, Miss Lucy Maud. St. Hilda's, Hornsea, East Yorkshire.
1898. *Greenly, Edward, F.G.S. 15 Madeira-road, Clevedon, Somerset.
1906. ‡Greenwood, Sir Hamar, Bart., M.P. National Liberal Club, Whitehall-place, S.W. 1.
1915. §Greenwood, William. 35 Belgrave-road, Oldham.
1915. ‡Greg, Henry P. Lode Hill, Styal.
1894. *Gregory, J. Walter, D.Sc., F.R.S., F.G.S. (Pres. C, 1907), Professor of Geology in the University of Glasgow.
1896. *Gregory, Professor Sir R. A., F.R.A.S. (Council, 1916– .) 17 Grosvenor-road, Westminster, S.W. 1.
1914. ‡Gregory, Miss U. J. The University, Glasgow.
1919. §Greves, E. H., M.D. 19 Poole-road, Bournemouth.
1914. ‡Grew, Mrs. 30 Cheyne-row, S.W.
1919. *Grier, Miss Lynda. Newnham College, Cambridge.
1894. *Griffith, C. L. T., Assoc.M.Inst.C.E. Gayton Corner, Harrow.
1908. §Griffith, Sir John P., M.R.I.A., M.Inst.C.E. Rathmines Castle Rathmines, Dublin.
1884. ‡Griffiths, E. H., M.A., D.Sc., F.R.S. (Pres. A, 1906; Pres. L, 1913; Council, 1911–17.) 5 Selwyn-gardens, Cambridge.
1884. ‡Griffiths, Mrs. 5 Selwyn-gardens, Cambridge.
1903. ‡Griffiths, Thomas P., J.P. 101 Manchester-road, Southport.
1888. *Grimshaw, James Walter, M.Inst.C.E. St. Stephen's Club, Westminster, S.W. 1.
1914. ‡Grinley, Frank. Wandella, Gale-street, Woolwich. N.S.W.
1894. ‡Groom, Professor P., M.A., F.L.S. North Park, Gerrard's Cross, Bucks.
1894. ‡Groom, T. T., M.A., D.Sc., F.G.S., Care of Professor Sollas, 48 Woodstock-road, Oxford.
1913. ‡Grove, W. B., M.A. 45 Duchess-road, Edgbaston, Birmingham.
1869. ‡Grubb, Sir Howard, F.R.S., F.R.A.S. Aberfoyle, Rathgar, Dublin.
1913. §Gruchy, G. F. B. de. Manoir de Noirmont, St. Aubin, Jersey.
1897. ‡Grünbaum, A. S., M.A., M.D. School of Medicine, Leeds.
1910. ‡Grundy, James. Ruislip, Teignmouth-road, Cricklewood, N.W. 2.
1919. *Gubbay, Mrs. Amelia. Penrallt, Kingskerswell, South Devon.
1913. ‡Guest, James J. University College, Gower-street, W.C. 1.
1915. §Guilleband, Claude W. St. John's College, Cambridge.
1887. ‡Guillemard, F. H. H., M.A., M.D. The Mill House, Trumpington, Cambridge.
1905. *Gunn, Donald. Royal Societies Club, St. James's-street, S.W. 1.
1909. ‡Gunne, J. R., M.D. Kenora, Ontario, Canada.
1909. ‡Gunne, W. J., M.D. Kenora, Ontario, Canada.
1894. ‡Günther, R. T. Magdalen College, Oxford.
1880. §Guppy, John J. Ivy-place, High-street, Swansea.
1904. *Gurney, Sir Eustace. Sprowston Hall, Norwich.
1916. ‡Gurney, Miss L. Mary. The Grove, Jesmond, Newcastle-on-Tyne.
1902. *Gurney, Robert. Ingham Old Hall, Stalham, Norfolk.

Year of Election.

1914. ‡Guthrie, Mrs. Blanche. 184A Ladbroke-grove, W. 10.
1906. *Gwynne-Vaughan, Mrs. Helen C. I., O.B.E., D.Sc., F.L.S. 93 Bedford Court-mansions, W.C. 1.

1905. ‡Hacker, Rev. W. J. Idutywa, Transkei, South Africa.
1908. *Hackett, Felix E. Royal College of Science, Dublin.
1916. ‡Hacking, Thomas. 33 Bowling Green-street, Leicester.
1881. *Haddon, Alfred Cort, M.A., Sc.D., F.R.S., F.Z.S. (Pres. H, 1902–1905; Council, 1902–08, 1910–17.) 3 Cranmer-road, Cambridge.
1914. ‡Haddon, Mrs. 3 Cranmer-road, Cambridge.
1911. *Haddon, Miss Kathleen. 3 Cranmer-road, Cambridge.
1888. *Hadfield, Sir Robert, Bart., D.Met., D.Sc., F.R.S., M.Inst. C.E. (Council, 1919–). 22 Carlton House-terrace, S.W. 1.
1913. ‡Hadley, H. E., B.Sc. School of Science, Kidderminster.
1915. ‡Hadow, Sir Henry, C.B.E., D.Mus., Principal of Armstrong College, Newcastle-on-Tyne.
1911. ‡Haigh, B. P., B.Sc. James Watt Engineering Laboratory, The University, Glasgow.
1906. ‡Hake, George W. Oxford, Ohio, U.S.A.
1894. ‡Haldane, John Scott, M.A., M.D., F.R.S. (Pres. I, 1908.) Cherwell, Oxford.
1919. §Haley, C. R. Municipal Buildings, Bournemouth.
1911. ‡Halket, Miss A. C. Bedford College, Regent's Park, N.W. 1.
1899. ‡Hall, Sir A. D., K.C.B., M.A., F.R.S. (Pres. M, 1914; Council, 1908–15.) Board of Agriculture, 4 Whitehall-place, S.W. 1.
1909. ‡Hall, Archibald A., M.Sc., Ph.D. Armstrong College, Newcastle-on-Tyne.
1914. ‡Hall, Dr. Cuthbert. Glenrowan, Paramatta, Sydney.
1879. *Hall, Ebenezer. Abbeydale Park, near Sheffield.
1854. *Hall, Hugh Fergie, F.G.S. Cissbury Court, West Worthing, Sussex.
1884. ‡Hall, Thomas Proctor, M.D. 1301 Davie-street, Vancouver, B.C., Canada.
1908. *Hall, Wilfred, Assoc.M.Inst.C.E. 9 Prior's-terrace, Tynemouth, Northumberland.
1913. ‡Hall-Edwards, J. The Elms, 112 Gough-road, Edgbaston, Birmingham.
1873. *Hallett, T. G. P., M.A. Claverton Lodge, Bath.
1888. §Halliburton, W. D., M.D., LL.D., F.R.S. (Pres. I, 1202; Council, 1897–1903, 1911–19), Professor of Physiology in King's College, London. Church Cottage, 17 Marylebone-road, N.W. 1.
1905. ‡Halliburton, Mrs. Church Cottage, 17 Marylebone-road, N.W. 1.
1904. *Hallidie, A. H. S. *Avondale, Chesterfield-road, Eastbourne.*
1919. *Hallsworth, Professor M. Armstrong College, Newcastle-on-Tyne.
1886. ‡Hambleton, G. W. 109 Ramsden-road, S.W. 12.
1908. *Hamel, Egbert Alexander de. Wigginton Lodge, Tamworth.
1883. *Hamel, Egbert D. de. Middleton Hall, Tamworth.
1915. ‡Hamer, J. St. James'-buildings, Oxford-street, Manchester.
1906. ‡Hamill, John Molyneux, M.A., M.B. 14 South-parade, Chiswick, W. 4.
1909. ‡Hamilton, F. C. Bank of Hamilton-chambers, Winnipeg, Canada.
1902. ‡Hamilton, Rev. T., D.D. Queen's College, Belfast.

Year of Election.

1909. ‡Hamilton, T. Glen, M.D. 264 Renton-avenue, Winnipeg, Canada.
1899. *Hanbury, Daniel. Castle Malwood, Lyndhurst, Hants.
1919. §Hanby, Wilfred. 24 Nelson-street, Rotherham.
1905. *Hancock, Strangman. Kennel Holt, Cranbrook, Kent.
1918. ‡Hankey, Norman Frederick. The Town Hall, Merthyr Tydfil.
1912. ‡Hankin, G. T. 150 Whitehall-court, S.W. 1.
1911. ‡Hann, H. F. 139 Victoria-road North, Southsea.
1906. §Hanson, David. Salterlee, Halifax, Yorkshire.
1904. §Hanson, E. K. Woodthorpe, Royston Park-road, Hatch End, Middlesex.
1914. ‡Happell, Mrs. Care of Miss E. M. Bundey, Molesworth-street, North Adelaide, South Australia.
1909. ‡Harcourt, George. Department of Agriculture, Edmonton, Alberta, Canada.
1902. *Hardcastle, Miss Frances. 3 Osborne-terrace, Newcastle-on-Tyne.
1892. *Harden, Arthur, Ph.D., D.Sc., F.R.S. Lister Institute of Preventive Medicine, Chelsea-gardens, Grosvenor-road, S.W. 1.
1877. ‡Harding, Stephen. Bower Ashton, Clifton, Bristol.
1894. ‡Hardman, S. C. 120 Lord-street, Southport.
1913. ‡Hardy, George Francis. 30 Edwardes-square, Kensington, W. 8.
1909. ‡Hardy, W. B., M.A., F.R.S. Gonville and Caius College, Cambridge.
1890. *Harker, Alfred, M.A., F.R.S., F.G.S. (Pres. C, 1911.) St. John's College, Cambridge.
1914. ‡Harker, Dr. George. The University, Sydney, N.S.W.
1896. ‡Harker, John Allen, O.B.E., D.Sc., F.R.S. Alston, Queen's-road, Teddington, S.W.
1875. *Harland, Rev. Albert Augustus, M.A., F.G.S., F.L.S., F.S.A. The Vicarage, Harefield, Middlesex.
1877. *Harland, Henry Seaton. 8 Arundel-terrace, Brighton.
1899. ‡Harman, Dr. N. Bishop, F.R.C.S. 108 Harley-street, W. 1.
1913. ‡Harmar, Mrs. 102 Hagley-road, Birmingham.
1868. *Harmer, F. W., M.A., F.G.S. Oakland House, Cringleford, Norwich.
1881. *Harmer, Sir Sidney F., K.B.E., M.A., Sc.D., F.R.S. (Pres. D, 1908; Council, 1916–), Keeper of the Department of Zoology, British Museum (Natural History), Cromwell-road, S.W. 142 Cromwell-road, S.W. 7.
1906. ‡Harper, J. B. 16 St. George's-place, York.
1913. ‡Harris, F. W. 132 and 134 Hurst-street, Birmingham.
1842. ‡Harris, G. W. Millicent, South Australia.
1909. ‡Harris, J. W. Civic Offices, Winnipeg.
1903. ‡Harris, Robert, M.B. Queen's-road, Southport.
1904. *Harrison, Frank L., B.A., B.Sc. Grammar School Cottage, St. John's, Antigua, B.W.I.
1904. ‡Harrison, H. Spencer, D.Sc. The Horniman Museum, Forest Hill, S.E.
1892. ‡Harrison, John. (Local Sec. 1892.) Rockville, Napier-road, Edinburgh.
1915. ‡Harrison, Launcelot. Quick Laboratory, Cambridge.
1892. ‡Harrison, Rev. S. N. Ramsey, Isle of Man.
1901. *Harrison, W. E. 17 Soho-road, Handsworth, Birmingham.
1919. §Harrison, W. H. Branksome Hall, Bournemouth.
1911. ‡Harrison-Smith, F., C.B. H.M. Dockyard, Portsmouth.

Year of Election.

1885. ‡Hart, Colonel C. J. (Local Sec. 1886.) Highfield Gate, Edgbaston, Birmingham.
1909. ‡Hart, John A. 120 Emily-street, Winnipeg, Canada.
1903. *Hart, Thomas Clifford. Brooklands, Blackburn.
1907. ‡Hart, W. E. Kilderry, near Londonderry.
1911. ‡Hart-Synnot, Ronald V. O. University College, Reading.
1893. *Hartland, E. Sidney, F.S.A. (Pres. H, 1906; Council, 1906-13.) Highgarth, Gloucester.
1905. ‡Hartland, Miss. Highgarth, Gloucester.
1886. *Hartog, Professor M. M., D.Sc. University College, Cork.
1887. ‡Hartog, P. J., B.Sc. University of London, South Kensington, S.W. 1.
1862. *Harwood, John. Woodsleigh, Heaton, near Bolton.
1893. §Haslam, Lewis. 8 Wilton-crescent, S.W. 1.
1911. *Hassé, H. R. The University, Bristol.
1903. *Hastie, Miss J. A. Care of Messrs. Street & Co., 30 Cornhill, E.C. 3.
1904. *Hastings, G. 17 Welbury-drive, Bradford, Yorkshire.
1903. ‡*Hastings, W. G. W.* 2 *Halsey-street, Cadogan-gardens, S.W.* 3.
1889. ‡Hatch, F. H., Ph.D., F.G.S. 15 Copse-hill, Wimbledon, S.W. 19.
1903. ‡Hathaway, Herbert G. 45 High-street, Bridgnorth, Salop.
1904. **Haughton, W. T. H. The Highlands, Great Barford, St. Neots.*
1908. §Havelock, T. H., M.A., D.Sc., F.R.S., Professor of Applied Mathematics in Armstrong College, Newcastle-on-Tyne. Rockliffe, Gosforth, Newcastle-on-Tyne.
1904. ‡Havilland, Hugh de. Eton College, Windsor.
1917. §Hawkes, Mrs. O. A. Merritt, M.Sc., B.Sc. 405 Hagley-road, Birmingham.
1887. *Hawkins, William. Earlston House, Broughton Park, Manchester.
1864. *Hawkshaw, John Clarke, M.A., M.Inst.C.E., F.G.S. (Council, 1881–87.) 22 Down-street, W. 1.
1887. *Haworth, Jesse. Woodside, Bowdon, Cheshire.
1916. ‡Haworth, John. The Employers' Parliamentary Association, 15 Cross-street, Manchester.
1913. ‡Haworth, John F. Withens, Barker-road, Sutton Coldfield.
1913. ‡Haworth, Mrs. Withens, Barker-road, Sutton Coldfield.
1919. §Hay, Alexander. East Anglian Institute of Agriculture, Chelmsford.
1885. *Haycraft, John Berry, M.D., B.Sc., F.R.S.E., Professor of Physiology in University College, Cardiff.
1900. §Hayden, H. H., C.I.E., F.R.S., F.G.S. Geological Survey, Calcutta, India.
1903. *Haydock, Arthur. High-street, Settle.
1913. §Hayward, Miss. 7 Abbotsford-road, Galashiels, N.B.
1903. ‡Hayward, Joseph William, M.Sc. Keldon, St. Marychurch, Torquay.
1896. *Haywood, Colonel A. G. 8 Carson-road, West Dulwich, S.E. 21.
1883. ‡Heape, Joseph R. Glebe House, Rochdale.
1882. *Heape, Walter, M.A., F.R.S. 10 King's Bench-walk, Temple, E.C. 4.
1909. ‡*Heard, Mrs. Sophie, M.B., Ch.B. Carisbrooke, Fareham, Hants.*
1902. ‡Heath, J. W. Royal Institution, Albemarle-street, W. 1.
1898. ‡Heath, R. S., M.A., D.Sc., Vice-Principal and Professor of Mathematics in the University of Birmingham.
1909. ‡Heathcote, F. C. C. Broadway, Winnipeg, Canada.
1883. ‡Heaton, Charles. Marlborough House, Hesketh Park, Southport.
1913. §Heaton, Howard. (Local Sec. 1913.) Wayside, Lode-lane, Solihull, Birmingham.

Year of Election.

1892. *Heaton, William H., M.A. (Local Sec., 1893), Principal of and Professor of Physics in University College, Nottingham.
1888. *Heawood, Edward, M.A. Briarfield, Church-hill, Merstham, Surrey.
1888. *Heawood, Percy J., Professor of Mathematics in Durham University. High Close, Hollinside-lane, Durham.
1887. *Hedges, Killingworth, M.Inst.C.E. 10 Cranley-place, South Kensington, S.W. 1.
1881. *Hele-Shaw, H. S., D.Sc., LL.D., F.R.S., M.Inst.C.E. (Pres. G, 1915.) 64 Victoria-street, S.W. 1.
1901. *Heller, W. M., B.Sc. Education Office, Marlborough-street, Dublin.
1911. ‡Hellyer, Francis E. Farlington House, Havant, Hants.
1887. ‡*Hembry, Frederick William, F.R.M.S. City-chambers.* 2 *St. Nicholas-street, Bristol.*
1908. ‡Hemmy, Professor A. S. Government College, Lahore.
1899. ‡Hemsalech, G. A., D.Sc. The Owens College, Manchester.
1905. *Henderson, Andrew. 17 Belhaven-terrace, Glasgow.
1905. *Henderson, Miss Catharine. 17 Belhaven-terrace, Glasgow.
1891. *Henderson, G. G., M.A., D.Sc., LL.D., F.R.S., F.I.C. (Pres. B. 1916), Regius Professor of Chemistry in the University of Glasgow.
1905. §Henderson, Mrs. 7 Marlborough-drive, Kelvinside, Glasgow.
1907. ‡Henderson, H. F. Felday, Morland-avenue, Leicester.
1906. ‡Henderson, J. B., D.Sc., Professor of Applied Mechanics in the Royal Naval College, Greenwich, S.E. 10.
1909. ‡Henderson, Veylien E. Medical Building, The University, Toronto, Canada.
1916. ‡Henderson, W. F. Moorfield, Claremont, Newcastle-on-Tyne.
1880. *Henderson, Admiral W. H., R.N. 3 Onslow Houses, S.W. 7.
1911. ‡Henderson, William Dawson. The University, Bristol.
1904. *Hendrick, James, B.Sc., F.I.C., Professor of Agriculture in Marischal College, Aberdeen.
1910. ‡Heney, T. W. Sydney, New South Wales.
1910. *Henrici Major E. O., R.E., A.Inst., C.E. War Office, Cornwall House, Stamford-street, S.E. 1.
1906. ‡Henry, Dr. T. A. Imperial Institute, S.W. 7.
1909. *Henshall, Robert. Sunnyside, Latchford, Warrington.
1916. ‡Henson, Right Rev. H. H., D.D., Lord Bishop of Hereford. The Palace, Hereford.
1892. ‡Hepburn, David, M.D., F.R.S.E., Professor of Anatomy in University College, Cardiff.
1904. ‡Hepworth, Commander M. W. C., C.B., R.N.R. Meteorological Office, South Kensington, S.W. 7.
1909. ‡Herbinson, William. 376 Ellice-avenue, Winnipeg, Canada.
1914. *Herdman, Miss C. Croxteth Lodge, Sefton Park, Liverpool.
1902. ‡Herdman, G. W., B.Sc., Assoc.M.Inst.C.E. Irrigation and Water Supply Department, Pretoria.
1887. *Herdman, William A., C.B.E., D.Sc., LL.D., F.R.S., F.R.S.E., F.L.S. (President Elect; General Secretary, 1903–19; Pres. D. 1895; Council, 1894–1900; Local Sec. 1896), Professor of Natural History in the University of Liverpool. Croxteth Lodge, Sefton Park, Liverpool.
1893. *Herdman, Mrs. Croxteth Lodge, Sefton Park, Liverpool.
1909. ‡Herdt, Professor L. A. McGill University, Montreal, Canada.

Year of Election.

1912. ‡Heron, David, D.Sc. Galton Eugenics Laboratory, University College, W.C. 1.
1912. *Heron-Allen, Edward, F.R.S., F.L.S., F.G.S. 33 Hamilton-terrace, N.W.; and Large Acres, Selsey Bill, Sussex.
1908. *Herring, Percy T., M.D., Professor of Physiology in the University, St. Andrews, N.B.
1874. §Herschel, Colonel John, R.E., F.R.S., F.R.A.S. Observatory House, Slough, Bucks.
1900. *Herschel, Rev. J. C. W. Braywood Vicarage, Winkfield, Windsor.
1913. ‡Hersey, Mayo Dyer, A.M. Bureau of Standards, Washington, U.S.A.
1905. ‡Hervey, Miss Mary F. S. 22 Morpeth-mansions, S.W.
1903. *Hesketh, Charles H. Fleetwood, M.A. Stocken Hall, Stretton, Oakham.
1895. §Hesketh, James. 5 Scarisbrick Avenue, Southport.
1913. ‡Hett, Miss Mary L. 53 Fordwych-road, West Hampstead, N.W.2.
1894. ‡Hewetson, G. H. (Local Sec. 1895.) 39 Henley-road, Ipswich.
1915. ‡*Hewison, William. Winfield, St. George's-cresent, Pendleton.*
1908. ‡Hewitt, Dr. C. Gordon. Central Experimental Farm, Ottawa.
1903. ‡Hewitt, E. G. W. 87 Princess-road, Moss Side, Manchester.
1903. ‡Hewitt, John Theodore, M.A., D.Sc., Ph.D., F.R.S. Clifford House, Staines-road, Bedfont, Middlesex.
1909. ‡Hewitt, W., B.Sc. 16 Clarence-road, Birkenhead.
1882. *Heycock, Charles T., M.A., F.R.S. 3 St. Peter's-terrace, Cambridge.
1883. ‡Heyes, Rev. John Frederick, M.A., F.R.G.S. St. Barnabas Vicarage, Bolton.
1866. *Heymann, Albert. West Bridgford, Nottinghamshire.
1912. §Heywood, H. B., D.Sc. 44 Manor-way, Ruislip.
1912. ‡Hickling, George, D.Sc., F.G.S. Professor of Geology in the Armstrong College, Newcastle-on-Tyne.
1877. §Hicks, W. M., M.A., D.Sc., F.R.S. (Pres. A, 1895), Crowhurst Hotel, Crowhurst, Sussex.
1886. ‡Hicks, Mrs. W. M., Crowhurst Hotel, Crowhurst, Sussex.
1887. *Hickson, Sydney J., M.A., D.Sc., F.R.S. (Pres. D, 1903; Local Secretary, 1915), Professor of Zoology in Victoria University, Manchester.
1864. *Hiern, W. P., M.A., F.R.S. The Castle, Barnstaple.
1914. ‡Higgins, J. M. Riversdale-road, Camberwell, Victoria.
1914. ‡Higgins, Mrs. J. M. Riversdale-road, Camberwell, Victoria.
1891. ‡Higgs, Henry, C.B., LL.B., F.S.S. (Pres. F, 1899; Council, 1904–06.) H.M. Treasury, Whitehall, S.W. 1.
1909. ‡Higman, Ormond. Electrical Standards Laboratory, Ottawa.
1913. *Higson, G. I., M.Sc. 11 Westbourne-road, Birkdale, Lancashire.
1907. ‡Hiley, E. V. (Local Sec. 1907.) Town Hall, Birmingham.
1911. *Hiley, Wilfrid E. Danesfield, Boar's Hill, Oxford.
1885. *Hill, Alexander, O.B.E., M.A., M.D. Hartley University College, Southampton.
1903. *Hill, Arthur W., M.A., F.L.S. Royal Gardens, Kew.
1906. ‡Hill, Charles A., M.A., M.B. 13 Rodney-street, Liverpool.
1919. *Hill, Cyril Francis. Druid's Croft, Kinnaird-avenue, Bromley.
1881. *Hill, Rev. Canon Edwin, M.A. The Rectory, Cockfield, Bury St. Edmunds.
1908. *Hill, James P., D.Sc., F.R.S., Professor of Zoology in University College, Gower-street, W.C. 1.
1911. ‡Hill, Leonard, M.B., F.R.S. (Pres. I, 1912.) Osborne House, Loughton, Essex.
1912. ‡Hill, M. D. Angelo's, Eton College, Windsor.

Year of Election.

1886. ‡Hill, M. J. M., M.A., Sc.D., F.R.S., Professor of Pure Mathematics in University College, W.C. 1.
1898. *Hill, Thomas Sidney. Langford House, Langford, near Bristol.
1907. *Hills, Colonel E. H., C.M.G., R.E., F.R.S., F.R.G.S. (Pres. E, 1908.) 1 Campden-hill, W. 8.
1920. M Hills, Mrs. Juliet. 1 Campden-hill, W. 8.
1903. *Hilton, Harold, D.Sc. 108 Alexandra-road, South Hampstead, N.W. 8.
1903. *Hind, Wheelton, M.D., F.G.S. Roxeth House, Stoke-on-Trent.
1910. ‡Hindle, Professor Edward, B.A., Ph.D., F.L.S. Biological Department, School of Medicine, Cairo.
1883. *Hindle, James Henry. 8 Cobham-street, Accrington.
1915. *Hindley, R. T. The Green-way, Macclesfield.
1898. ‡Hinds, Henry. 57 Queen-street, Ramsgate.
1911. ‡Hinks, Arthur R., C.B.E., M.A., F.R.S., Sec. R.G.S. Royal Geographical Society, Kensington Gore, S.W. 7.
1903. **Hinmers, Edward. Glentwood, South Downs-drive, Hale, Cheshire.*
1915. ‡Hitchcock, E. F. Toynbee Hall, Commercial-street, E. 1.
1914. ‡Hoadley, C. A., M.Sc. Weenabah, Ballarat, Victoria.
1919. §Hobbs, A. Chingin Khal, Queen's Park-avenue, Boscombe.
1919. §Hobbs, Miss Dorothy. Chingin Khal, Queen's Park-avenue, Boscombe.
1919. §Hobbs, Miss Phyllis. Chingin Khal, Queen's Park-avenue, Boscombe,
1899. ‡Hobday, Henry. Hazelwood, Crabble Hill, Dover.
1914. ‡Hobson, A. Kyme. Overseas Club, 266 Flinders-street, Melbourne.
1887. *Hobson, Bernard, M.Sc., F.G.S. Thornton, Hallamgate-road, Sheffield.
1904. ‡Hobson, Ernest William, Sc.D., F.R.S. (Pres. A, 1910), Sadleirian Professor of Pure Mathematics in the University of Cambridge. The Gables, Mount Pleasant, Cambridge.
1913. ‡Hodges, Ven. Archdeacon George, M.A. Ely.
1916. *Hodgkin, T. E., M.A. Old Ridley, Stocksfield, Northumberland.
1887. *Hodgkinson, Alexander M.B., B.Sc. Bradshaigh, Lower Bourne, near Farnham, Surrey.
1880. ‡*Hodgkinson, W. R. Eaton, C.B.E., Ph.D., F.R.S.E., Professor of Chemistry and Physics in the Royal Artillery College, Woolwich.* 18 *Glenluce-road, Blackheath, S.E.* 3.
1919. *Hodgson, Benjamin. 114 Bishop-road, Horfield, Bristol.
1909. ‡Hodgson, R. T., M.A. Collegiate Institute, Brandon, Manitoba, Canada.
1898. ‡Hodgson, T. V. Municipal Museum and Art Gallery, Plymouth.
1919. *Hodson, Miss C. B. S., F.L.S. Steephurst, Bedale's School, Petersfield.
1915. ‡*Hoffert, H. H., D.Sc. The Gables, Marple, Stockport.*
1904. ‡Hogarth, D. G., M.A., C.M.G. (Pres. H, 1907; Council, 1907–10.) 20 St. Giles's, Oxford.
1914. ‡Hogben, George, M.A., F.G.S. 9 Tinakori-road, Wellington, New Zealand.
1908. ‡Hogg, Right Hon. Jonathan. Stratford, Rathgar, Co. Dublin.
1911. ‡Holbrook, Colonel A. R. Warleigh, Grove-road South, Southesa.
1907. ‡Holden, Colonel Sir H. C. L., K.C.B., R.A., F.R.S. Gifford House, Blackheath, S.E. 3.
1883. ‡Holden, John J. 73 Albert-road, Southport.

Year of Election.

1887. *Holder, Henry William, M.A. Whingarth, Skelsmergh, near Kendal.
1913. ‡Holder, Sir John C., Bart. Pitmaston, Moor Green, Birmingham.
1900. ‡Holdich, Colonel Sir Thomas H., K.C.M.G., K.C.I.E., C.B. (Pres. E, 1902.) 41 Courtfield-road, S.W. 7.
1887. *Holdsworth, C. J., J.P. Fernhill, Alderley Edge, Cheshire.
1904. §Holland, Charles E. 9 Downing-place, Cambridge.
1903. ‡Holland, J. L., B.A. 3 Primrose-hill, Northampton.
1896. ‡Holland, Mrs. Lowfields House, Hooton, Cheshire.
1898. ‡Holland, Sir Thomas H., K.C.I.E., F.R.S., F.G.S. (Pres. C, 1914), Professor of Geology in the Victoria University, Manchester.
1889. ‡Holländer, Bernard, M.D. 35A Welbeck-street, W. 1.
1906. *Hollingworth, Miss. Leithen, Newnham-road, Bedford.
1920. M Holmes, Miss Marion G., B.Sc. University College, Cardiff.
1916. *Holmes, Arthur, B.Sc., F.G.S. Elmhurst, Langley-road, Merton Park, S.W. 19.
1883. *Holmes, Mrs. Basil. 37 Corfton-road, Ealing, W. 5.
1866. *Holmes, Charles. 47 Wellington-road, Bush Hill Park.
1882. *Holmes, Thomas Vincent, F.G.S. 28 Croom's-hill, Greenwich, S.E. 10.
1903. *Holt, Alfred, M.A., D.Sc. Messrs. Holt, Thompson & Co., Binns-road, Liverpool.
1915. §Holt, Alderman Sir E., Bart., C.B.E., J.P. Woodthorpe, Bury Old-road, Heaton Park, Manchester.
1875. *Hood, John. Longreach House, Keynsham, near Bristol.
1904. §Hooke, Rev. D. Burford, D.D. 20 Cavendish-road, Henleaze, Bristol.
1892. ‡Hooker, Reginald H. Boroughfield, Bricket-road, St. Albans.
1908. *Hooper, Frank Henry. Deepdene, Streatham Common, S.W. 16.
1865. *Hooper, John P. Deepdene, Streatham Common, S.W. 16.
1877. *Hooper, Rev. Samuel F., M.A. Lydlinch Rectory, Sturminster Newton, Dorset.
1904. ‡*Hopewell-Smith, A., M.R.C.S.* 37 *Park-street, Grosvenor-square, S.W.* 1.
1905. *Hopkins, Charles Hadley. Junior Constitutional Club, 101 Piccadilly, W. 1.
1913. ‡Hopkins, F. Gowland, M.A., D.Sc., M.B., F.R.S. (Pres. I, 1913), Trinity College, and Saxmeadham, Grange-road, Cambridge.
1884. *Hopkinson, Charles. (Local Sec. 1887.) The Limes, Didsbury, near Manchester.
1882. *Hopkinson, Edward, M.A., D.Sc. Ferns, Alderley Edge, Cheshire.
1905. ‡Hopkinson, Mrs. John. Ellerslie, Adams-road, Cambridge.
1898. *Hornby, R., M.A. Haileybury College, Hertford.
1910. ‡Horne, Arthur S. Kerlegh, Cobham, Surrey.
1885. ‡Horne, John, LL.D., F.R.S., F.R.S.E., F.G.S. (Pres. C, 1901.) 20 Merchiston-gardens, Edinburgh.
1903. ‡Horne, William, F.G.S. Leyburn, Yorkshire.
1902. ‡Horner, John. Chelsea, Antrim-road, Belfast.
1905. *Horsburgh, E. M., M.A., B.Sc., Lecturer in Technical Mathematics in the University of Edinburgh.
1887. ‡Horsfall, T. C. Swanscoe Park, near Macclesfield.
1908. ‡Horton F. The Pines, Englefield Green, Surrey.
1884. *Hotblack, G. S. Brundall, Norwich.
1906. *Hough, Miss Ethel M. The School House, Brentwood, Essex.
1859. ‡Hough, Joseph, M.A., F.R.A.S. Codsall Wood, Wolverhampton.

Year of Election.

1896. *Hough, S. S., M.A., F.R.S., F.R.A.S., His Majesty's Astronomer at the Cape of Good Hope. Royal Observatory, Cape Town.
1905. ‡Houghting, A. G. L. Glenelg, Musgrave-road, Durban, Natal.
1886. ‡Houghton, F. T. S., M.A., F.G.S. 188 Hagley-road, Birmingham.
1914. ‡Houghton, T. H., M.Inst.C.E. 63 Pitt-street, Sydney, N.S.W.
1908. ‡Houston, David, F.L.S. Royal College of Science, Dublin.
1919. *Houston, Dr. R. A. 45 Kirklee-road, Glasgow.
1904. *Howard, Mrs. G. L. C. Agricultural Research Institute, Pusa, Bengal, India.
1887. *Howard, S. S. 56 Albemarle-road, Beckenham, Kent.
1919. *Howard-Watson, Captain J. A., F.R.G.S. 1 Eaton Bank, Crosby-road, Waterloo, Liverpool.
1901. §Howarth, E., F.R.A.S. Public Museum, Weston Park, Sheffield.
1907. ‡Howarth, O. J. R., O.B.E., M.A. (Assistant Secretary.) Hawthorn Lodge, Eardley-road, Sevenoaks.
1914. ‡Howchin, Professor Walter. University of Adelaide, South Australia.
1911. *Howe, Professor G. W. O., D.Sc. Elmswood, Malden, Surrey.
1905. ‡Howick, Dr. W. P.O. Box 503, Johannesburg.
1863. ‡Howorth, Sir H. H., K.C.I.E., D.C.L., F.R.S., F.S.A. 45 Lexham-gardens, W. 8.
1887. §Hoyle, William E., M.A., D.Sc. (Pres. D, 1907.) National Museum of Wales, City Hall, Cardiff.
1903. ‡Hübner, Julius. Ash Villa, Cheadle Hulme, Cheshire.
1913. ‡Huddart, Mrs. J. A. 2 Chatsworth-gardens, Eastbourne.
1919. *Hudleston, L. J. 53 Christchurch-road, Reading.
1913. ‡Hughes, Alfred, M.A., Professor of Education in the University of Birmingham. 29 George-road, Edgbaston, Birmingham.
1871. *Hughes, George Pringle, J.P., F.R.G.S. Middleton Hall, Wooler, Northumberland.
1903. ‡Hulton, Campbell G. Palace Hotel, Southport.
1905. ‡*Hume, D. G. W. 55 Gladstone-street, Dundee, Natal.*
1919. §Hume, R. H., M.A. Stanley House School, Bristol-road, Birmingham.
1911. *Hume, Dr. W. F. Helwan, Egypt.
1914. ‡Humphrey, G. D. Care of Messrs. Lane & Peters, Burrinjuck, New South Wales.
1904. *Humphreys, Alexander C., Sc.D., LL.D., President of the Stevens Institute of Technology, Hoboken, New Jersey, U.S.A.
1907. ‡Humphries, Albert E. Coxe's Lock Mills, Weybridge.
1891. *Hunt, Cecil Arthur. Southwood, Torquay.
1914. ‡Hunt, H. A. Weather Bureau, Melbourne.
1881. ‡Hunter, F. W. 16 Old Elvet, Durham.
1889. ‡Hunter, Mrs. F. W. 16 Old Elvet, Durham.
1916. §Hunter, G. B. The Willows, Jesmond, Newcastle-on-Tyne.
1916. §Hunter, Summers. 1 Manor-terrace, Tynemouth.
1909. ‡Hunter, W. J. H. 31 Lynedoch-street, Glasgow.
1901. *Hunter, William. Evirallan, Stirling.
1903. ‡Hurst, Charles C., F.L.S. Burbage, Hinckley.
1861. *Hurst, William John. Drumaness, Ballynahinch, Co. Down, Ireland.
1913. ‡Hutchins, Miss B. L. 8 Bradmore-road, Oxford.
1914. §Hutchins, D. E. c/o Messrs T. Cook and Son, next General Post Office, Wellington, New Zealand.
1894. *Hutchinson, A., M.A., Ph.D. (Local Sec. 1904.) Pembroke College, Cambridge.

Year of Election.

1912. §Hutchinson, Dr. H. B. Rothamsted Experimental Station Harpenden, Herts.
1903. §Hutchinson, Rev. H. N., M.A. 17 St. John's Wood Park, N.W. 8.
1887. *Hutton, J. Arthur. The Woodlands, Alderley Edge, Cheshire.
1901. *Hutton, R. S., D.Sc. Dam House, Mushroom-lane, Sheffield.
1871. *Hyett, Sir Francis A. Painswick House, Painswick, Stroud, Gloucestershire.
1900. *Hyndman, H. H. Francis. 3 New-court, Lincoln's Inn, W.C. 2.

1919. §Ibbett, F. W., M.A. (Local Sec. 1919). Education Offices, Bournemouth.
1908. ‡Idle, George. 43 Dawson-street, Dublin.
1883. ‡Idris, T. H. W. 4 St. Alban's Villas, Highgate-road, N. W. 5.
1884. *Iles, George. 5 Brunswick-street, Montreal, Canada.
1906. ‡Iliffe, J. W. Oak Tower, Upperthorpe, Sheffield.
1913. §Illing, Vincent Charles, B.A., F.G.S. The Chestnuts, Hartshill, Atherstone, Warwickshire.
1915. ‡*Imms, A. D. West Wood, The Beeches, West Didsbury.*
1885. §Im Thurn, Sir Everard F., C.B., K.C.M.G. (Pres. H, 1914; Council, 1913– .) 39 Lexham-gardens, W. 8.
1907. §Ingham, Charles B. Moira House, Eastbourne.
1919. *Inglis, C. E., O.B.E., M.A., Professor of Engineering in the University of Cambridge. Ball's Grove, Grantchester.
1905. §Innes, R. T. A., F.R.A.S. Union Observatory, Johannesburg.
1901. *Ionides, Stephen A. 802 Equitable-building, Denver, Colorado.
1913. ‡Irvine, James, F.R.G.S. Richmond-buildings, Chapel-street, Liverpool.
1912. ‡Irvine, J. C., C.B.E., Ph.D., F.R.S., Professor of Chemistry in the University of St. Andrews.
1882. §Irving, Rev. A., B.A., D.Sc. Hockerill Vicarage, Bishop's Stortford, Herts.
1908. ‡*Irwin, Alderman John.* 33 *Rutland-square, Dublin.*

1915. ‡Jack, A. J. 30 Amhurst-road, Withington, Manchester.
1914. ‡Jack, A. K., B.Sc. Agricultural College, Dookie, Victoria.
1909. ‡Jacks, Professor L. P. 28 Holywell, Oxford.
1883. *Jackson, Professor A. H., B.Sc. 349 Collins-street, Melbourne, Australia.
1915. ‡Jackson, E. J. W., B.A. The University, Edmund-street, Birmingham.
1874. *Jackson, Frederick Arthur. Belmont, Somenos, Vancouver Island, B.C., Canada.
1919. *Jackson, Right Hon. F. Huth. 12 Tokenhouse-yard, E.C. 2.
1883. *Jackson, F. J. 35 Leyland-road, Southport.
1883. ‡Jackson, Mrs. F. J. 35 Leyland-road, Southport.
1899. ‡Jackson, Geoffrey A. 31 Harrington-gardens, Kensington, S.W. 7.
1913. *Jackson, H. Gordon, M.Sc. Mason College, Birmingham.
1906. *Jackson, James Thomas, M.A. Engineering School, Trinity College, Dublin.
1919. *Jackson, John. Royal Observatory, Greenwich, S.E. 10.
1887. ‡Jacobson, Nathaniel, J.P. Westwood, Polygon-road, Higher Crumpsall, Manchester.
1905. *Jaffé, Arthur, M.A. New-court, Temple, E.C. 4.

Year of Election.

1874. *Jaffé, John. Villa Jaffé, 38 Promenade des Anglais, Nice, France.
1906. ‡Jalland, W. H. Museum-street, York.
1891. *James, Charles Russell. Brynteg, Dene-road, Northwood.
1916. §James, Rev. E. O., B.Litt., F.C.S. St. Peter's Vicarage, Limehouse, E. 14.
1904. ‡James, Thomas Campbell. University College, Aberystwyth.
1896. *Jameson, H. Lyster, M.A., Ph.D. Board of Agriculture, 43 Parliament-street, S.W. 1.
1889. *Japp, F. R., M.A., Ph.D., LL.D., F.R.S. (Pres. B, 1898.) 36 Twyford-avenue, West Acton, W. 3.
1910. *Japp, Henry, M.Inst.C.E. 59 Beaver Hall-hill, Montreal, Canada.
1896. *Jarmay, Sir John G., K.B.E. Hartford Lodge, Hartford, Cheshire.
1913. ‡Jarrard, W. J. The University, Sheffield.
1903. ‡Jarratt, J. Ernest. (Local Sec. 1903.) 22 Hesketh-road, Southport.
1904. *Jeans, J. H., M.A., F.R.S. (Council, 1917– .) Cleveland Lodge, Dorking.
1916. *Jeffreys, Harold. St. John's College, Cambridge.
1912. ‡Jehu, T. J., M.A., M.D., Professor of Geology in the University of Edinburgh.
1908. *Jenkin, Arthur Pearse, F.R.Met.Soc. Trewirgie, Redruth.
1909. *Jenkins, Miss Emily Vaughan. 14 Eldon-road, Hampstead, N.W. 3.
1893. *Jennings, G. E. Ashleigh, Ashleigh-road, Leicester.
1889. ‡Jevons, F. B., M.A. Hatfield Hall, Durham.
1907. *Jevons, Miss H. W. 17 Tredegar-square, Bow, E. 3.
1905. §Jeyes, Miss Gertrude, B.A. 16 Harborne-road, Edgbaston, Birmingham.
1914. ‡Jobbins, G. G. Geelong Club, Geelong, Victoria.
1909. *Johns, Cosmo, F.G.S., M.I.M.E. Burngrove, Pitsmoor-road, Sheffield.
1890. *Johnson, Thomas, D.Sc., F.L.S., Professor of Botany in the Royal College of Science, Dublin.
1902. *Johnson, Rev. W., B.A., B.Sc. Wath Rectory, Melmerby, S.O., Yorkshire.
1898. *Johnson, W. Claude, M.Inst.C.E. Broadstone, Coleman's Hatch, Sussex.
1899. ‡Johnston, Colonel Sir Duncan A., K.C.M.G., C.B., C.B.E., R.E., F.R.G.S. (Pres. E, 1909.) 8 Lansdowne-crescent, Edinburgh.
1883. ‡Johnston, Sir H. H., G.C.M.G., K.C.B., F.R.G.S. St. John's Priory, Poling, near Arundel.
1913. ‡Johnston, James. Oak Bank-avenue, Manchester.
1909. *Johnston, J. Weir, M.A. 129 Anglesea-road, Dublin.
1913. ‡Johnston, Dr. S. J. Department of Biology, The University, Sydney, N.S.W.
1908. ‡Johnston, Swift Paine. 1 Hume-street, Dublin.
1909. §Jolly, Professor W. A., M.B., D.Sc. South African College, Cape Town.
1888. ‡Joly, John, M.A., D.Sc., F.R.S., F.G.S. (Pres. C, 1908), Professor of Geology and Mineralogy in the University of Dublin. Geological Department, Trinity College, Dublin.
1887. ‡Jones, D. E., B.Sc. Eryl Dag, Radyr, Cardiff.
1913. *Jones, Daniel, M.A., Lecturer on Phonetics at University College, London, W.C.
1904. ‡Jones, Miss E. E. Constance. Girton College, Cambridge.

Year of Election.

1890. ‡JONES, Rev. EDWARD, F.G.S. Primrose Cottage, Embsay, Skipton.
1896. ‡Jones, E. Taylor, D.Sc. University College, Bangor.
1903. ‡Jones, Evan. Ty-Mawr, Aberdare.
1907. *Jones, Mrs. Evan. 39 Hyde Park-gate, S.W. 7.
1887. ‡Jones, Francis, F.R.S.E., F.C.S. 17 Whalley-road, Whalley Range, Manchester.
1891. *JONES, Rev. G. HARTWELL, D.D. Nutfield Rectory, Redhill, Surrey.
1883. *Jones, George Oliver, M.A. Inchyra House, 21 Cambridge-road, Waterloo, Liverpool.
1912. ‡Jones, J. H. The University, Glasgow.
1913. ‡Jones, O. T., M.A., D.Sc., F.G.S., Professor of Geology in the University College of Wales. Fenton, Caradoc-road, Aberystwyth.
1905. ‡Jones, Miss Parnell. The Rectory, Llanddewi Skyrrid, Abergavenny, Monmouthshire.
1901. ‡Jones, R. E., J.P. Oakley Grange, Shrewsbury.
1902. ‡Jones, R. M., M.A. Royal Academical Institution, Belfast.
1908. ‡Jones, R. Pugh, M.A. County School, Holyhead, Anglesey.
1912. §Jones, W. Neilson, M.A. Bedford College, Regent's Park, N.W. 1.
1913. ‡Jourdain, Miss Eleanor F. St. Hugh's College, Oxford.
1883. ‡Joyce, Rev. A. G., B.A. St. John's Croft, Winchester.
1886. ‡Joyce, Hon. Mrs. St. John's Croft, Winchester.
1905. ‡*Judd, Miss Hilda M., B.Sc. Berrymead, 6 Lichfield-road, Kew.*
1905 §Julian, Mrs Forbes, F.G.S. Redholme, Braddon's Hill-road, Torquay.
1914. ‡Julius, G. A., B.Sc. Culwulla-chambers, 67 Castlereagh-street, Sydney, N.S.W.
1905. §JURITZ, CHARLES F., M.A., D.Sc., F.I.C., Agricultural Research Chemist. Department of Agriculture, Cape Town.

1888. ‡KAPP, GISBERT, M.Sc., M.Inst.C.E., M.Inst.E.E. (Pres. G, 1913), Professor of Electrical Engineering in the University of Birmingham. 43 Upland-road, Selly Park, Birmingham.
1913. ‡Kay, Henry, F.G.S. 16 Wretham-road, Handsworth, Birmingham.
1915. §Kay, Max M. 82 Daisy Bank-road, Victoria Park, Manchester.
1913. ‡Kaye, G. W. C. 76 Addison-gardens, Kensington, W. 14.
1904. ‡Kayser, Professor H. The University, Bonn, Germany.
1892. ‡KEANE, CHARLES A., Ph.D. Sir John Cass Technical Institute, Jewry-street, Aldgate, E.C. 1.
1913. ‡Kebby, Charles H. 75 Sterndale-road, West Kensington Park, W.
1908. ‡KEEBLE, FREDERICK W., C.B.E., M.A., Sc.D., F.R.S. (Pres. K, 1912), Director of the Royal Horticultural Gardens, Wisley. Weyton, St. George's-hill, Weybridge.
1911. *KEITH, ARTHUR, M.D., LL.D., F.R.S., F.R.C.S. (Pres. H., 1919; Council, 1917– .) Royal College of Surgeons, Lincoln's Inn-fields, W.C. 2.
1884. ‡Kellogg, J. H., M.D. Battle Creek, Michigan, U.S.A.
1908. ‡Kelly, Captain Vincent Joseph. Montrose, Donnybrook, Co. Dublin.
1911. ‡Kelly, Miss. Montrose, Merton-road, Southsea.
1902. *Kelly, William J., J.P. 25 Oxford-street, Belfast.

Year of Election.

1885. §KELTIE, Sir J. SCOTT, LL.D., F.R.G.S., F.S.S. (Pres. E, 1897; Council 1898–1904, 1919–.) 2 Rosecroft-avenue, Hampstead, N.W.3.
1887. ‡Kemp, Harry. 55 Wilbraham-road, Chorlton-cum-Hardy, Manchester.
1891. ‡KENDALL, PERCY F., M.Sc., F.G.S., Professor of Geology in the University of Leeds.
1919. §Kendrick, T. D. 25 Park-hill, Moseley, Birmingham.
1875. ‡KENNEDY, Sir ALEXANDER B. W., LL.D., F.R.S., M.Inst.C.E. (Pres. G, 1894.) Athenæum Club, S.W. 1.
1906. ‡Kennedy, Robert Sinclair. Glengall Ironworks, Millwall, E. 14.
1908. ‡Kennedy, William. 40 Trinity College, Dublin.
1905. *Kennerley, W. R. P.O. Box 158, Pretoria.
1913. ‡KENRICK, W. BYNG. (Local Sec. 1913.) Metchley House, Somerset-road, Edgbaston, Birmingham.
1893. §KENT, A. F. STANLEY, M.A., D.Sc., F.L.S., F.G.S.. College of Technology, Manchester.
1913. *Kenyon, Joseph, B.Sc., F.I.C. 9 Bainton-road, Oxford.
1857. *Ker, André Allen Murray. Newbliss House, Newbliss, Ireland.
1915. ‡Kerfoot, E. H. Springwood Hall, Ashton-under-Lyne.
1915. ‡Kerfoot, Thomas. Pole Bank Hall, Gee Cross, Cheshire.
1881. ‡KERMODE, P. M. C. Claghbene, Ramsey, Isle of Man.
1913. §Kerr, George L. 39 Elmbank-crescent, Glasgow.
1909. ‡Kerr, Hugh L. 68 Admiral-road, Toronto, Canada.
1892. ‡KERR, J. GRAHAM, M.A., F.R.S., Regius Professor of Zoology in the University of Glasgow.
1889. ‡Kerry, W. H. R. The Sycamores, Windermere.
1910. §KERSHAW, J. B. C. 9 Grosvenor-road, Colwyn Bay, North Wales.
1869. *Kesselmeyer, Charles Augustus. Roseville, Vale-road, Bowdon, Cheshire.
1869. *Kesselmeyer, William Johannes. Edelweiss Villa, 19 Broomfield-lane, Hale, Cheshire.
1903. ‡Kewley, James. Balek Papan, Koltei, Dutch Borneo.
1883. *Keynes, J. N., M.A., D.Sc., F.S.S. 6 Harvey-road, Cambridge.
1906. ‡Kidner, Henry, F.G.S. Bisterne Close, Burley, Brockenhurst.
1886. §KIDSTON, ROBERT, LL.D., F.R.S., F.R.S.E., F.G.S. 12 Clarendon-place, Stirling.
1901. *Kiep, J. N. 137 West George-street, Glasgow.
1885. *Kilgour, Alexander. Loirston House, Cove, near Aberdeen.
1896. *Killey, George Deane, J.P. Bentuther, 11 Victoria-road, Waterloo, Liverpool.
1890. ‡KIMMINS, C. W., M.A., D.Sc. The Old Heritage, Chailey, Sussex.
1914. ‡Kincaid, Miss Hilda S., D.Sc. Tarana, Kinkora-road, Hawthorn, N.S.W.
1875. *KINCH, EDWARD, F.I.C. Komaba, Haslemere, Surrey.
1875. *King, F. Ambrose. Avonside, Clifton, Bristol.
1914. §King, Miss Georgina. c/o Kelso King, Esq., 120 Pitt-street, Sydney, N.S.W.
1871. *King, Rev. Herbert Poole. The Rectory, Stourton, Bath.
1883. *King, John Godwin. Stonelands, East Grinstead.
1883. *King, Joseph, M.P. Sandhouse, Witley, Godalming.
1908. ‡King, Professor L. A. L., M.A. St. Mungo's College Medical School, Glasgow.
1860. *King, Mervyn Kersteman. Merchants' Hall, Bristol.
1912. *King W. B. R., M.A., O.B.E. Sedgwick Museum, Cambridge.
1912. ‡King, W. J. Harding. 25 York House, Kensington, W.

Year of Election.

1870. ‡King, William, M.Inst.C.E. 5 Beach-lawn, Waterloo, Liverpool.
1913. *King, William Wickham, F.G.S. Winds Point, Hagley, near Stourbridge.
1909. ‡Kingdon, A. 197 Yale-avenue, Winnipeg, Canada.
1903. ‡Kingsford, H. S., M.A. 8 Elsworthy-terrace, N.W. 3.
1900. ‡Kipping, Professor F. Stanley, D.Sc., Ph.D., F.R.S. (Pres. B, 1908.) University College, Nottingham.
1899. *Kirby, Miss C. F. 8 Windsor-court, Moscow-road, W. 2.
1913. §Kirkaldy, Professor A. W., M.Com. (Pres. F, 1916.) University College, Nottingham.
1916. ‡Kirkby, Rev. J. P. Saham Rectory, Watton, Norfolk.
1915. *Kitson, A. E. 109 Worple-road, Wimbledon, S.W. 19.
1901. §Kitto, Edward. Pennance, Preston, Paignton, South Devon.
1915. ‡Knecht, E., Ph.D., Professor of Chemistry in the University of Manchester. 131 Sussex-road, Southport.
1914. §Knibbs, G. H., C.M.G., F.R.A.S., F.S.S., Commonwealth Statistician. Rialto, Collins-street, Melbourne.
1917. §Knight, Lieut.-Colonel C. Morley. 94 Piccadilly, W. 1.
1886. ‡Knight, Captain J. M., F.G.S. Bushwood, Wanstead, Essex.
1888. ‡Knott, Professor Cargill G., D.Sc., F.R.S.E. 42 Upper Gray-street, Edinburgh.
1887. *Knott, Herbert, J.P. Sunnybank, Wilmslow, Cheshire.
1887. *Knott, John F. Edgemoor, Burbage, Derbyshire.
1906. *Knowles, Arthur J., B.A., M.Inst.C.E. 10 Drayton-court, Drayton-gardens, S.W. 10.
1915. *Knowles, Sir Lees, Bart., C.V.O., O.B.E. Westwood, Pendlebury, near Manchester.
1916. ‡Knowles, W. H. Sun-buildings, Newcastle-on-Tyne.
1874. ‡Knowles, William James. Flixton-place, Ballymena, Co. Antrim.
1915. §Knox, Principal George, F.G.S. Heol Isaf, Radyr, Glamorgan.
1902. ‡Knox, R. Kyle, LL.D. 1 College-gardens, Belfast.
1875. *Knubley, Rev. Canon E. P., M.A. Steeple Ashton Vicarage, Trowbridge.
1883. ‡Knubley, Mrs. Steeple Ashton Vicarage, Trowbridge.
1888. *Kunz, G. F., M.A., Ph.D., Sc.D. Care of Messrs. Tiffany & Co. 11 Union-square, New York City, U.S.A.

1919. *Lace, Richard, F.R.G.S. Santan, Isle of Man.
1903. *Lafontaine, Rev. H. C. de. 52 Albert-court, Kensington Gore, S.W. 7.
1904. ‡Lake, Philip. St. John's College, Cambridge.
1904. ‡Lamb, C. G. Ely Villa, Glisson-road, Cambridge.
1889. *Lamb, Edmund, M.A. Borden Wood, Liphook, Hants.
1915. ‡*Lamb, Francis W. Lyndene, High Lane, near Stockport.*
1887. ‡Lamb, Horace, M.A., LL.D., D.Sc., F.R.S. (Pres. A, 1904), Professor of Mathematics in the Victoria University, Manchester. 6 Wilbraham-road, Fallowfield, Manchester.
1893. *Lamplugh, G. W., F.R.S., F.G.S. (Pres. C, 1906.) 13 Beaconsfield-road, St. Albans.
1914. ‡Lane, Charles. Care of John Sanderson & Co., William-street, Melbourne.
1898. *Lang, William H., M.B., F.R.S. (Pres. K, 1915), Professor of Cryptogamic Botany in the University of Manchester. 2 Heaton-road, Withington, Manchester.
1886. *Langley, J. N., M.A., D.Sc., F.R.S. (Pres. I, 1899; Council, 1904–07), Professor of Physiology in the University of Cambridge. Trinity College, Cambridge.

Year of Election.

1915. ‡Langton, J. L., M.Sc. Municipal School of Technology, Manchester.
1865. ‡Lankester, Sir E. Ray, K.C.B., M.A., LL.D., D.Sc., F.R.S. (President, 1906; Pres. D, 1883; Council, 1889–90, 1894–95, 1900–02.) Chinehead, Westcliff-road, Bournemouth.
1884. ‡Lanza, Professor G. Massachusetts Institute of Technology, Boston, U.S.A.
1911. ‡Lapthorn, Miss. St. Bernard's, Grove-road South, Southsea.
1909. ‡Larard, C. E., Assoc.M.Inst.C.E. 14 Leaside-avenue, Muswell Hill, N. 10.
1887. ‡Larmor, Alexander. Craglands, Helen's Bay, Co. Down.
1881. ‡Larmor, Sir Joseph, M.A., D.Sc., F.R.S. (Pres. A, 1900), Lucasian Professor of Mathematics in the University of Cambridge. St. John's College, Cambridge.
1883. ‡Lascelles, B. P., M.A. Headland, Mount Park, Harrow.
1911. ‡*Lattey, R. T.* 243 *Woodstock-road, Oxford.*
1900. *Lauder, Alexander, D.Sc., Lecturer in Agricultural Chemistry in the Edinburgh and East of Scotland College of Agriculture, Edinburgh.
1913. *Laurie, Mrs. E. B. 11 Marine-parade, Hoylake.
1892. ‡Laurie, Malcolm, B.A., D.Sc., F.L.S. School of Medicine, Surgeons' Hall, Edinburgh.
1907. *Laurie, Robert Douglas, M.A. Zoology Department, University College of Wales, Aberystwyth.
1870. *Law, Channell. Ilsham Dene, Torquay.
1914. ‡Lawrence, A. H. Urunga, N.S.W.
1905. ‡Lawrence, Miss M. Roedean School, near Brighton.
1911. *Lawson, A. Anstruther, D.Sc., F.R.S.E., F.L.S., Professor of Botany in the University, Sydney, N.S.W.
1908. ‡Lawson, H. S., B.A. Buxton College, Derbyshire.
1908. ‡Lawson, William, LL.D. 27 Upper Fitzwilliam-street, Dublin.
1914. ‡Layard, J. W. Bull Cliff, Felixstowe.
1888. ‡Layard, Miss Nina F., F.L.S. Rookwood, Fonnereau-road, Ipswich.
1913. ‡Lea, F. C., D.Sc., Professor of Civil Engineering in the University of Birmingham. 36 Mayfield-road, Moseley, Birmingham.
1883. *Leach, Charles Catterall. Seghill, Northumberland.
1894. *Leahy, A. H., M.A., Professor of Mathematics in the University of Sheffield. 92 Ashdell-road, Sheffield.
1905. ‡Leake, E. O. 5 Harrison-street, Johannesburg.
1901. *Lean, Dr. George. Corran, Lochgilphead, Argyllshire.
1904. *Leathem, J. G. St. John's College, Cambridge.
1910. §Lebour, Miss M. V., M.Sc. Zoological Department, The University, Leeds.
1912. ‡Lechmere, A. Eckley, M.Sc. Townhope, Hereford.
1895. *Ledger, Rev. Edmund. Protea, Doods-road, Reigate.
1914. ‡Lee, Charles Alfred. Tenterfield, N.S.W.
1896. §Lee, Rev. H. J. Barton. 7 First-avenue, Broadway, Blackpool.
1907. ‡Lee, Mrs. Barton. 7 First-avenue, Broadway, Blackpool.
1919. §Lee, Miss Eva M. 55 Logan-road, Bishopston, Bristol.
1909. §Lee, I. L. 61 Broadway, New York City, U.S.A.
1909. ‡Lee, Rev. J. W., D.D. 5043 Washington-avenue, St. Louis, Missouri, U.S.A.
1894. *Lee, Mrs. W. The Nook, Forest Row, Sussex.
1909. ‡Leeming, J. H., M.D. 406 Devon-court, Winnipeg, Canada.

Year of Election.

1892. *Lees, Charles H., D.Sc., F.R.S., Professor of Physics in the East London College, Mile End, E. Greenacres, Dryhill Park-road, Tonbridge.
1912. ‡Lees, John. Pitscottie, Cupar-Fife, N.B.
1906. ‡Lees, Robert. Victoria-street, Fraserburgh.
1915. *Lees, S., M.A. 51 Chesterton-road, Cambridge.
1889. *Leeson, John Rudd, M.D., C.M., F.L.S., F.G.S. Clifden House, Twickenham, Middlesex.
1906. ‡Leetham, Sidney. Elm Bank, York.
1912. ‡Leggat, W. G. Bank of Scotland, Dundee.
1912. ‡Legge, James G. Municipal Buildings, Liverpool.
1910. §Leigh, H. S. Brentwood, Worsley, near Manchester.
1915. ‡Leigh, T. B. Arden, Bredbury, near Stockport.
1891. ‡Leigh, W. W. Glyn Bargoed, Treharris, R.S.O., Glamorganshire.
1903. ‡Leighton, G. R., M.D., F.R.S.E. Local Government Board, Edinburgh.
1906. ‡Leiper, Robert T., M.B., F.Z.S. London School of Tropical Medicine, Royal Albert Dock, E. 16.
1913. ‡Leith, Professor R. F. C., M.A., M.Sc. Pathological Laboratory, The University, Birmingham.
1903. *Lempfert, R. G. K., M.A. 54c Radcliffe-square, S.W. 10.
1901. §Leonard, J. H., B.Sc. Natural History Museum, South Kensington. S.W. 7.
1915. §Leslie, Miss M. S., D.Sc. 1 Park View-terrace, Halton, near Leeds.
1914. ‡Le Souef, W. H. D., C.M.Z.S. Zoological Gardens, Parkville, Victoria, Australia.
1913. ‡Lessing, R., Ph.D. 317 High Holborn, W.C. 1.
1912. *Lessner, C., F.C.S. Carril, Spain.
1890. *Lester, Joseph Henry. 5 Grange-drive, Monton Green, Manchester.
1904. *Le Sueur, H. R., D.Sc. Chemical Laboratory, St. Thomas's Hospital, S.E. 1.
1896. ‡Leverhulme, The Right Hon. Lord. Thornton Manor, Thornton Hough, Cheshire.
1904. *Lewis, Mrs. Agnes S., LL.D. Castle Brae, Chesterton-lane, Cambridge.
1870. ‡Lewis, Alfred Lionel. 35 Beddington-gardens, Wallington, Surrey.
1891. ‡Lewis, Professor D. Morgan, M.A. University College, Aberystwyth,
1913. ‡Lewis, E. O. Gwynfa, Alma-street, Brynmawr.
1899. ‡Lewis, Professor E. P. University of California, Berkeley, U.S.A.
1910. ‡Lewis, Francis J., D.Sc., F.L.S., Professor of Biology in the University of Alberta, Edmonton, Alberta, Canada.
1919. §Lewis, Miss Gertrude. Montrose, Queen's-road, Bournemouth.
1904. ‡Lewis, Hugh. Glanafrau, Newtown, Montgomeryshire.
1920. MR Lewis, T., D.Sc., F.R.S. 10 Chesterford-gardens, N.W. 3.
1910. *Lewis, T. C. West Home, West-road, Cambridge.
1911. §Lewis, W. C. McC., M.A., D.Sc., Professor of Physical Chemistry in the University of Liverpool.
1906. ‡Liddiard, James Edward, F.R.G.S. Rodborough Grange, Bournemouth.
1913. *Lillie, D. G. St. John's College, Cambridge.
1908. ‡Lilly, W. E., M.A., Sc.D. 39 Trinity College, Dublin.
1919. *Lindemann, Professor F. A. Clarendon Laboratory, Oxford.

Year of Election.

1904. ‡Link, Charles W. 14 Chichester-road, Croydon.
1913. *Lishman, G. P., D.Sc., F.I.C. Chemical Laboratory, Lambton Coke Works, Fence Houses, Co. Durham.
1888. ‡Lister, J. J., M.A., F.R.S. (Pres. D, 1906.) St. John's College, Cambridge.
1861. *Liveing, G. D., M.A., F.R.S. (Pres. B, 1882; Council, 1888–95; Local Sec. 1862.) Newnham, Cambridge.
1876. *Liversidge, Archibald, M.A., F.R.S., F.C.S., F.G.S., F.R.G.S. Fieldhead, George-road, Kingston Hill, Surrey.
1902. §Llewellyn, Evan. Workmen's Institute and Hall. Blaenavon.
1912. ‡Lloyd, Miss Dorothy Jordan. 16 Ampton-road, Edgbaston, Birmingham.
1909. §Lloyd, George C., Secretary of the Iron and Steel Institute. 28 Victoria-street, S.W. 1.
1903. ‡Lloyd, Godfrey I. H. The University of Toronto, Canada.
1919. §Lloyd, John A. 6 Montgomery-road, Sheffield.
1892. ‡Loch, Sir C. S., D.C.L. Denison House, Vauxhall Bridge-road, S.W. 1.
1905. ‡Lochrane, Miss T. 8 Prince's-gardens, Dowanhill, Glasgow.
1904. ‡Lock, Rev. J. B. Herschel House, Cambridge.
1863. ‡Lockyer, Sir J. Norman, K.C.B., LL.D., D.Sc., F.R.S. (President, 1903; Council, 1871–76, 1901–02.) 16 Penywern-road, S.W.
1902. *Lockyer, Lady. 16 Penywern-road, S.W.
1914. ‡Lockyer, Ormonde H. S. 126 Webster-street, Ballarat, Victoria.
1900. ‡Lockyer, W. J. S., Ph.D. 16 Penywern-road, S.W.
1886. *Lodge, Alfred, M.A. (Council, 1913-15.) 330 Banbury-road, Oxford.
1914. ‡Lodge, Miss Lorna L. Mariemont, Edgbaston, Birmingham.
1914. ‡Lodge, Miss Norah M. Mariemont, Edgbaston, Birmingham.
1875. *Lodge, Sir Oliver J., D.Sc., LL.D., F.R.S. (President, 1913; Pres. A, 1891; Council, 1891–97, 1899–1903, 1912–13.) Birmingham.
1914. ‡Lodge, Lady. Mariemont, Edgbaston, Birmingham.
1894. *Lodge, Oliver W. F. Nurton Farm, Tintern, Monmouthshire.
1915. §Lomas, L. H., B.Sc. Butley Cottage, Prestbury, Cheshire.
1915. ‡Lomax, James, A.L.S. Oakenbottom, Tonge, Bolton.
1899. §Loncq, Emile. 6 Rue de la Plaine, Laon, Aisne, France.
1903. ‡Long, Frederick. The Close, Norwich.
1905. ‡Long, W. F. City Engineer's Office, Cape Town.
1910. *Longden, G. A. Draycott Lodge, Derby.
1904. *Longden, J. A., M.Inst.C.E. Chislehurst, Marlborough-road, Bournemouth.
1901. *Longstaff, Major Frederick V., F.R.G.S. Care of Wimbledon Common Branch, London County Westminster and Parr's Bank, Wimbledon, S.W. 19.
1875. *Longstaff, George Blundell, M.A., M.D., F.C.S., F.S.S. Highlands, Putney Heath, S.W.
1881. *Longstaff, Mrs. Ll. W. Ridgelands, Wimbledon, S.W. 1. Care of Mrs. A. F. Wedgwood, The Grange, Ightham Kent.
1896. ‡Louis, Henry, D.Sc., Professor of Mining in the Armstrong College of Science, Newcastle-on-Tyne.
1887. *Love, A. E. H., M.A., D.Sc., F.R.S. (Pres. A, 1907), Professor of Natural Philosophy in the University of Oxford. 34 St. Margaret's-road, Oxford.
1886. *Love, E. F. J., M.A., D.Sc. The University, Melbourne, Australia.
1904. *Love, J. B., LL.D. Outlands, Devonport.
1876. *Love, James, F.R.A.S., F.G.S., F.Z.S. 33 Clanricarde-gardens, W. 2.

Year of Election.

1916. ‡Loveday, Thomas. 1 Grosvenor-villas, Newcastle-on-Tyne.
1908. *Low, Alexander, M.A., M.D. The University, Aberdeen.
1909. ‡Low, David, M.D. 1927 Scarth-street, Regina, Saskatchewan, Canada.
1912. ‡Low, William. Balmakewan, Seaview, Monifieth.
1885. §Lowdell, Sydney Poole. Baldwin's Hill, East Grinstead, Sussex.
1891. §Lowdon, John. St. Hilda's, Barry, Glamorgan.
1885. *Lowe, Arthur C. W. Gosfield Hall, Halstead, Essex.
1886. *Lowe, John Landor, B.Sc., M.Inst.C.E. 27 Palace-mansions, Addison Bridge, W. 14.
1894. ‡Lowenthal, Miss Nellie. Woodside, Egerton, Huddersfield.
1903. *Lowry, Dr. T. Martin, C.B.E., F.R.S. 17 Eliot-park, Lewisham, S.E. 13.
1913. §Lucas, Harry. Hilver, St. Agnes-road, Moseley, Birmingham.
1919. §Luck, H. Courtenay. Courtenay, Zillmere, Queensland.
1891. *Lucovich, Count A. Tyn-y-parc, Whitchurch, near Cardiff.
1906. ‡Ludlam, Ernest Bowman. 32 Storey's-way, Cambridge.
1883. *Lupton, Arnold, M.Inst.C.E., F.G.S. 7 Victoria-street, S.W. 1.
1914. ‡Lupton, Mrs. 7 Victoria-street, S.W. 1.
1903. ‡Lyddon, Ernest H. Lisvane, near Cardiff.
1919. §Lyde, Professor L. W., M.A., F.R.G.S. (Pres. E, 1919). Northwick Lodge, Peterborough-road, Harrow.
1916. ‡Lye, W. T. Leagrave Hall, near Luton, Beds.
1871. ‡Lyell, Sir Leonard, Bart., F.G.S. Kinnordy, Kirriemuir.
1916. ‡Lyle, R. P. Rankin. Holmwood, Clayton-road, Newcastle-on-Tyne.
1914. ‡Lyle, Professor T. R., M.A., Sc.D., F.R.S. Irving-road, Toorak, Victoria, Australia.
1912. *Lynch, Arthur, M.A., M.P. 80 Antrim-mansions, Haverstock Hill, N.W. 3.
1919. §Lyon, H. Claude. Shalimar, Branksome Park, Bournemouth.
1907. *Lyons, Lieut-Colonel Henry George, D.Sc., F.R.S. (Pres E. 1915; Council, 1912–15). 3 Cambridge-square, Hyde Park W. 2.
1908. ‡Lyster, George H. 34 Dawson-street, Dublin.
1908. ‡Lyster, Thomas W., M.A. National Library of Ireland, Kildare-street, Dublin.

1878. ‡MacAlister, Sir Donald, K.C.B., M.A., M.D., LL.D., B.Sc., Principal of the University of Glasgow.
1919. §MacAlister, D. A. Care of National Provincial and Union Bank, 53 Baker-street, W.
1904. ‡Macalister, Miss M. A. M. Torrisdale, Cambridge.
1896. ‡Macallum, Professor A. B., Ph.D., Sc.D., F.R.S. (Pres. I, 1910; Local Sec. 1897.) 59 St. George-street, Toronto, Canada.
1914. ‡McAlpine, D. Berkeley-street, Hawthorn, Victoria, Australia.
1915. §Macara, Sir C. W., Bart. Ardmore, St. Anne's-on-Sea.
1909. ‡MacArthur, J. A., M.D. Canada Life-building, Winnipeg, Canada.
1896. *Macaulay, F. S., M.A. The Chesters, Vicarage-road, East Sheen, S.W.
1904. *Macaulay, W. H. King's College, Cambridge.
1919. §McBain, Dr. J. W. The University, Bristol.
1896. ‡MacBride, E. W., M.A., D.Sc., F.R.S. (Pres. D, 1916), Professor of Zoology in the Imperial College of Science and Technology, S.W. 7.

Year of Election.

1902. *Maccall, W. T., M.Sc. Technical College, Sunderland.
1912. ‡McCallum, George Fisher. 142 St. Vincent-street, Glasgow.
1912. ‡McCallum, Mrs. Lizzie. 142 St. Vincent-street, Glasgow.
1908. ‡McCarthy, Edward Valentine, J.P. Ardmanagh House, Glenbrook, Co. Cork.
1909. ‡McCarthy, J. H. Public Library, Winnipeg, Canada.
1884. *McCarthy, J. J., M.D. 11 Wellington-road, Dublin.
1904. *McClean, Lieut.-Colonel Frank Kennedy. Rusthall House, Tunbridge Wells.
1919. §McClean, W. N. 1 Onslow-gardens, S.W.
1906. ‡McClure, Rev. E. 80 Eccleston-square, S.W. 1.
1878. *M'Comas, Henry. 12 Elgin-road, Dublin.
1908. *McCombie, Hamilton, M.A., Ph.D. The University, Birmingham.
1914. *McCombie, Mrs. Hamilton. The University, Birmingham.
1901. *MacConkey, Alfred. Lister Lodge, Elstree, Herts.
1915. §McConnel, John W. Wellbank, Prestwich.
1901. ‡McCrae, John, Ph.D. 7 Kirklee-gardens, Glasgow.
1912. ‡MacCulloch, Rev. Canon J. A., D.D. The Rectory, Bridge of Allan.
1905. §McCulloch, Principal J. D. Free College, Edinburgh.
1915. ‡McDonald, Dr. Archie W. Glencoe, Huyton, Liverpool.
1909. ‡MacDonald, Miss Eleanor. Fort Qu'Appelle, Saskatchewan, Canada.
1904. ‡Macdonald, H. M., M.A., F.R.S., Professor of Mathematics in the University of Aberdeen.
1905. ‡McDonald, J. G. P.O. Box 67, Bulawayo.
1900. ‡MacDonald, J. Ramsay.
1905. ‡Macdonald, J. S., B.A., F.R.S. (Pres. I, 1911), Professor of Physiology in the University of Sheffield.
1909. ‡MacDonell, John, M.D. Portage-avenue, Winnipeg, Canada.
1909. *MacDougall, R. Stewart. The University, Edinburgh.
1915. *McDougall, Robert, B.Sc. Lerryn, Carr Wood-road, Cheadle Hulme, Stockport.
1912. ‡McDougall, Dr. W., F.R.S. 89 Banbury-road, Oxford.
1916. ‡McDowall, Professor J. W. East Cottingwood, Morpeth.
1906. ‡McFarlane, John, M.A. The University of Aberdeen.
1885. ‡Macfarlane, J. M., D.Sc., F.R.S.E., Professor of Biology in the University of Pennsylvania. Lansdowne, Delaware Co., Pennsylvania, U.S.A.
1909. ‡Macgachen, A. F. D. 281 River-avenue, Winnipeg, Canada.
1908. ‡McGrath, Sir Joseph, LL.D. (Local Sec. 1908.) Royal University of Ireland, Dublin.
1906. ‡Macgregor, D. H., M.A. Trinity College, Cambridge.
1896. *MacGregor-Morris, J. T. 3 Lyndhurst-road, Hampstead, N.W. 3.
1867. *McIntosh, W. C., M.D., LL.D., F.R.S., F.R.S.E., F.L.S. (Pres. D, 1885). 2 Abbotsford-crescent, St. Andrews, N.B.
1909. ‡McIntyre, Alexander. 142 Maryland-avenue, Winnipeg, Canada.
1909. ‡McIntyre, Daniel. School Board Offices, Winnipeg, Canada.
1912. ‡McIntyre, J. Lewis, M.A., D.Sc. Abbotsville, Cults, Aberdeenshire.
1909. ‡McIntyre, W. A. 339 Kennedy-street, Winnipeg, Canada.
1884. §MacKay, A. H., B.Sc., LL.D. 163 Queen-street, Dartmouth, Nova Scotia, Canada.
1919. §Mackay, Brigadier-General J. G. Physical Laboratory, The University, Sydney, New South Wales.

Year of Election.

1913. *Mackay, John. 85 Bay-street, Toronto, Canada.
1915. ‡Mackay, John. 46 Acomb-street, Manchester.
1885. ‡Mackay, John Yule, M.D., LL.D., Principal of and Professor of Anatomy in University College, Dundee.
1912. ‡Mackay, R. J. 27 Arkwright-road, Hampstead, N.W. 3.
1919. §McKay, R. F. 36 Stevenage-road, S.W. 6.
1908. ‡McKay, William, J.P. Clifford-chambers, York.
1873. ‡McKendrick, John G., M.D., LL.D., F.R.S., F.R.S.E. (Pres. I, 1901; Council, 1903–09), Emeritus Professor of Physiology in the University of Glasgow. Maxieburn, Stonehaven, N.B.
1909. ‡McKenty, D. E. 104 Colony-street, Winnipeg, Canada.
1907. ‡McKenzie, Professor Alexander, M.A., D.Sc., Ph.D., F.R.S. University College, Dundee.
1905. ‡Mackenzie, Hector. Standard Bank of South Africa, Cape Town.
1897. ‡McKenzie, John J. 61 Madison-avenue, Toronto, Canada.
1910. ‡Mackenzie, K. J. J., M.A. 10 Richmond-road, Cambridge.
1909. §MacKenzie, Kenneth. Royal Alexandra Hotel, Winnipeg, Canada.
1901. *Mackenzie, Thomas Brown. Netherby, Manse-road, Motherwell, N.B.
1912. ‡Mackenzie, William, J.P. 22 Meadowside, Dundee.
1872. *Mackey, J. A. United University Club, Pall Mall East, S.W. 1.
1901. ‡Mackie, William, M.D. 13 North-street, Elgin.
1887. ‡Mackinder, Sir H. J., M.A., M.P., F.R.G.S. (Pres. E, 1895; Council, 1904–05.) 10 Chelsea-court, Chelsea Embankment, S.W. 3.
1911. ‡Mackinnon, Miss D. L. University College, Dundee.
1916. *Mackley, Edward H. Hawk's-road, Gateshead.
1915. §McLardy, Samuel. Basford Mount, Higher Crumpsall, Manchester.
1893. *McLaren, Mrs. E. L. Colby, M.B., Ch.B. 137 Tettenhall-road, Wolverhampton.
1901. ‡Maclay, William. Thornwood, Langside, Glasgow.
1901. ‡McLean, Angus, B.Sc. Harvale, Meikleriggs, Paisley.
1892. *Maclean, Magnus, M.A., D.Sc., F.R.S.E. (Local Sec. 1901), Professor of Electrical Engineering, Technical College, Glasgow.
1912. §McLean, R. C., B.Sc. Duart, Holmes-road, Reading.
1908. ‡McLennan, J. C., Ph.D., F.R.S., Professor of Physics in the University of Toronto, Canada.
1868. ‡McLeod, Herbert, LL.D., F.R.S. (Pres. B, 1892; Council, 1885–90.) 109 Church-road, Richmond, Surrey.
1909. ‡MacLeod, M. H. C.N.R. Depôt, Winnipeg, Canada.
1883. ‡MacMahon, Major Percy A., D.Sc., LL.D., F.R.S. (Trustee, 1913– ; General Secretary, 1902–13; Pres. A, 1901; Council, 1898–1902.) 27 Evelyn-mansions, Carlisle-place, S.W. 7.
1909. ‡McMillan, The Hon. Sir Daniel H., K.C.M.G. Government House, Winnipeg, Canada.
1902. ‡McMordie, Robert J. Cabin Hill, Knock, Co. Down.
1914. ‡Macnab, Angus D. Oakbank, Tullamarine, Victoria, Australia.
1914. ‡Macnicol, A. N. 31 Queen-street, Melbourne.
1878. ‡Macnie, George. 59 Bolton-street, Dublin.
1905. §Macphail, S. Rutherford, M.D. Rowditch, Derby.
1909. ‡MacPhail, W. M. P.O. Box 88, Winnipeg, Canada.
1907. ‡Macrosty, Henry W. 29 Hervey-road, Blackheath, S.E. 3.
1906. ‡Macturk, G. W. B. 15 Bowlalley-lane, Hull.
1908. ‡McVittie, R. B., M.D. 62 Fitzwilliam-square North, Dublin.
1908. ‡McWalter, J. C., M.D., M.A. 19 North Earl-street, Dublin.

Year of Election.

1902. ‡McWeeney, Professor E. J., M.D. 84 St. Stephen's-green, Dublin.
1910. ‡McWilliam, Dr. Andrew. Kalimate, B.N.R., near Calcutta.
1905. ‡Magenis, Lady Louisa. 34 Lennox-gardens, S.W. 1.
1909. ‡Magnus, Laurie, M.A. 12 Westbourne-terrace, W. 2.
1875. *Magnus, Sir Philip, Bart., B.Sc., B.A., M.P. (Pres. L, 1907.) 16 Gloucester-terrace, Hyde Park, W. 2.
1908. *Magson, Egbert H. Westminster College, Horseferry-road, S.W. 1.
1907. *Mair, David. Civil Service Commission, Burlington-gardens, W. 1.
1902. *Mairet, Mrs. Ethel M. Cruntsfield, Ditchling, Sussex.
1914. ‡Maitland, A. Gibb. Geological Survey, Perth, Western Australia.
1913. ‡Maitland, T. Gwynne, M.D. Southerndowne, Augustus-road, Edgbaston, Birmingham.
1908. *Makower, W., M.A., D.Sc. Air Ministry Laboratory, W/T Section, Imperial College of Science and Technology, S.W. 7.
1914. ‡Malinowski, B. London School of Economics, Clare Market, W.C. 2.
1920. Malcolm, C. W. G., F.R.S.E. Christ's College, Cambridge.
1912. ‡Malloch, James, M.A., F.S.A. (Scot.). Training College, Dundee.
1905. ‡Maltby, Lieutenant G. R., R.N. 54 St. George's-square, S.W. 1.
1915. ‡Mandleberg, G. C. Redclyffe, Victoria Park, Manchester.
1919. §Mangham, Sydney. 2 Eastfield-road, Benton, Newcastle-on-Tyne.
1903. ‡Manifold, C. C. 16 St. James's-square, S.W. 1.
1915. §Manson, John Sinclair, M.D. 8 Winmarleigh-street, Warrington.
1902. *Marchant, E. W., D.Sc., David Jardine Professor of Electrical Engineering in the University of Liverpool.
1912. ‡Marchant, Rev. James, C.B.E., F.R.S.E. 42 Great Russell-street, W.C. 1.
1898. *Mardon, Heber. Cliffden, Teignmouth, South Devon.
1911. *Marett, R. R., D.Sc. (Pres. H, 1916.) Exeter College, Oxford.
1905. ‡Marks, Samuel. P.O. Box 379, Pretoria.
1905. ‡Marloth, R., M.A., Ph.D. P.O. Box 359, Cape Town.
1881. *Marr, J. E., M.A., D.Sc., F.R.S., F.G.S. (Pres. C, 1896; Council, 1896–1902, 1910–14), Woodwardian Professor of Geology in the University of Cambridge. St. John's College, Cambridge.
1892. *Marsden-Smedley, J. B. Lea Green, Cromford, Derbyshire.
1883. *Marsh, Henry Carpenter. 147 Brondesbury-road, N.W. 2.
1887. ‡Marsh, J. E., M.A., F.R.S. University Museum, Oxford.
1915. ‡Marsh, J. H., M.D. Cumberland House, Macclesfield.
1889. *Marshall, Alfred, M.A., LL.D., D.Sc. (Pres. F, 1890.) Balliol Croft, Madingley-road, Cambridge.
1912. ‡Marshall, Professor C. R., M.A., M.D. The Medical School, Dundee.
1919. *Marshall, Rev. Edward S., F.L.S. West Monkton Rectory, Taunton.
1904. ‡Marshall, F. H. A. University of Edinburgh.
1889. ‡Marshall, Frank. Claremont House, Newcastle-on-Tyne.
1905. ‡Marshall, G. A. K. 6 Chester-place, Hyde Park-square, W. 2.
1919. §Martel, Major G. L. The Barracks, Christchurch, Hants.
1899. ‡Martin, Miss A. M. Park View, 32 Bayham-road, Sevenoaks.
1911. ‡Martin, Professor Charles James, M.D., D.Sc., F.R.S., Director of the Lister Institute, Chelsea-gardens, S.W. 3.
1889. *Martin, Thomas Henry, Assoc.M.Inst.C.E. Windermere, Mount Pleasant-road, Hastings.
1912. ‡Martin, W. H. Blyth. (Local Sec. 1912.) City Chambers, Dundee.
1916. §Martin, William, M.A., M.D. West Villa, Akenside-terrace, Newcastle-on-Tyne.

Year of Election.

1911. §Martindell, E. W., M.A. Royal Anthropological Institute, 50 Great Russell-street, W.C. 1.
1913. ‡Martineau, Lieut.-Colonel Ernest, V.D. Ellerslie, Augustus-road, Edgbaston, Birmingham.
1913. §Martineau, P. E. The Woodrow, near Bromsgrove, Worcester.
1907. ‡Masefield, J. R. B., M.A. Rosehill, Cheadle, Staffordshire.
1905. *Mason, Justice A. W. Supreme Court, Pretoria.
1913. *Mason, Edmund W., B.A. 2 York-road, Edgbaston, Birmingham.
1915. **Mason, Rev. W. A. Parker. Hulme Grammar School, Alexandra Park, Manchester.*
1913. ‡Mason, William. Engineering Laboratory, The University, Liverpool.
1891. *Massey, William H., M.Inst.C.E. Twyford, R.S.O., Berkshire.
1885. ‡Masson, David Orme, D.Sc., F.R.S., Professor of Chemistry in the University of Melbourne.
1910. ‡Masson, Irvine, M.Sc. University College, W.C. 1.
1905. §Massy, Miss Mary. Orestone, St. Mary Church, Torquay.
1901. *Mather, G. R. Sunnyville, Park-crescent, Wellingborough.
1910. *Mather, Thomas, F.R.S., Professor of Electrical Engineering in the City and Guilds of London Institute, Exhibition-road, S.W. 7.
1915. ‡Mather, Right Hon. Sir William, M.Inst.C.E. Bramble Hill, Bramshaw, New Forest.
1909. ‡Mathers, Mr. Justice. 16 Edmonton-street, Winnipeg, Canada.
1913. ‡Matheson, Miss M. Cecile. Birmingham Women's Settlement, 318 Summer-lane, Birmingham.
1908. ‡Matheson, Sir R. E., LL.D. Charlemont House, Rutland-square, Dublin.
1894. ‡Mathews, G. B., M.A., F.R.S. 7 Menai View, Bangor, North Wales.
1902. ‡Matley, C. A., D.Sc. Military Accounts Department, 6 Esplanade East, Calcutta, India.
1904 ‡Matthews, D. J. The Laboratory, Citadel Hill, Plymouth
1899. *Maufe, Herbert B., B.A., F.G.S. P.O. Box 366, Salisbury, Rhodesia.
1914. ‡Maughan, M. M., B.A., Director of Education. Parkside, South Australia.
1893. ‡Mavor, Professor James. University of Toronto, Canada.
1905. *Maylard, A. Ernest. 1 Windsor-terrace West, Glasgow.
1905. ‡Maylard, Mrs. 1 Windsor-terrace West, Glasgow.
1904. ‡Mayo, Rev. J., LL.D. 6 Warkworth-terrace, Cambridge.
1916. ‡Measham, Miss C. E. C. 128 New-walk, Leicester.
1912. ‡Meek, Alexander, M.Sc., Professor of Zoology in the Armstrong College of Science, Newcastle-on-Tyne.
1913. §Megson, A. L. Cambridge-street, Manchester.
1915. §Melland, W. 23 King-street, Manchester.
1883. ‡Mellis, Rev. James. 23 Part-street, Southport.
1879. *Mellish, Henry. Hodsock Priory, Worksop.
1881. §Melrose, James. Clifton Croft, York.
1905. *Melvill, E. H. V., F.G.S., F.R.G.S. P.O. Val, Standerton District, Transvaal.
1901. ‡Mennell, F. P., F.G.S. 49 London Wall, E.C. 2.
1913. *Mentz-Tolley, Richard, J.P. Lynn Hall, Lichfield.
1909. ‡Menzies, Rev. James, M.D. Hwaichingfu, Honan, China.
1919. §Mercier, Charles. Clovelly, Poole-road, Bournemouth West.
1914. ‡Meredith, Mrs. C. M. 55 Bryansburn-road, Bangor, Co. Down.
1905. ‡Meredith, H. O., O.B.E., M.A., Professor of Economics in Queen's University, Belfast. 55 Bryansburn-road, Bangor, Co. Down.

Year of Election.

1899. *Merrett, William H., F.I.C. Hatherley, Grosvenor-road, Wallington, Surrey.
1899. ‡Merryweather, J. C. 4 Whitehall-court, S.W. 1.
1915. ‡Merton, Thomas R. 25 Gilbert-street, W. 1.
1916. *Merz, Charles H. Collingwood-buildings, Newcastle-on-Tyne.
1889. *Merz, John Theodore. The Quarries, Newcastle-upon-Tyne.
1914. §Messent, A. E. 80 Regent-street, Millswood, Goodwood, South Australia.
1905. ‡Methven, Cathcart W. Club Arcade, Smith-street, Durban.
1896. §Metzler, W. H., Ph.D., Professor of Mathematics in Syracuse University, Syracuse, New York, U.S.A.
1915. ‡Meunier, Stanislas. Gas Works, Stockport.
1915. ‡Meunier, Mrs. 16 Gibson-road, Heaton Chapel, Stockport.
1903. *Micklethwait, Miss Frances M. G. 17 St. Mary's-terrace, Paddington, W. 2.
1881. *Middlesbrough, The Right Rev. Richard Lacy, D.D., Bishop of, Bishop's House, Middlesbrough.
1904. ‡Middleton, Sir T. H., K.B.E., C.B., M.A. (Pres. M. 1912). Development Commission, Dean's-yard, S.W. 1.
1894. *Miers, Sir Henry A., M.A., D.Sc., F.R.S., F.G.S. (Pres. C, 1905; Pres. L, 1910), Vice-Chancellor of the University of Manchester. Birch Heys, Cromwell Range, Fallowfield, Manchester.
1885. ‡Mill, Hugh Robert, D.Sc., LL.D., F.R.S.E., F.R.G.S. (Pres. E, 1901.) 62 Camden-square, N.W. 1.
1905. ‡Mill, Mrs. H. R. 62 Camden-square, N.W. 1.
1912. ‡Millar, Dr. A. H. (Local Sec. 1912.) Albert Institute, Dundee.
1889. *Millar, Robert Cockburn. 30 York-place, Edinburgh.
1909. §Miller, A. P. Glen Miller, Ontario, Canada.
1915. ‡Miller, Dr. Alexander K. 4 Darley-avenue, West Didsbury.
1895. ‡Miller, Thomas, M.Inst.C.E. 9 Thoroughfare, Ipswich.
1897. *Miller, Willet G., Provincial Geologist. Provincial Geologist's Office, Toronto, Canada.
1919. §Millin, S. Shannon. 28 St. Kevin's Park, Dartry-road, Dublin.
1904. ‡Millis, C. T. Hollydene, Wimbledon Park-road, Wimbledon.
1905. ‡Mills, Mrs. A. A. Ceylon Villa, Blinco-grove, Cambridge.
1908. ‡Mills, Miss E. A. Nurney, Glenagarey, Co. Dublin.
1868. *Mills, Edmund J., D.Sc., F.R.S., F.C.S. 64 Twyford-avenue, West Acton, W. 3.
1917. *Mills, Frederick, J.P., D.L., M.Inst.C.E. Llwyn-dû Court, Abergavenny.
1908. ‡Mills, John Arthur, M.B. Durham County Asylum, Winterton, Ferryhill.
1919. §Mills, W. H. Jesus College, Cambridge.
1902. ‡Mills, W. Sloan, M.A. Vine Cottage, Donaghmore, Newry.
1907. ‡Milne, A., M.A. University School, Hastings.
1910. ‡Milne, J. B. Cross Grove House, Totley, near Sheffield.
1910. *Milne, James Robert, D.Sc., F.R.S.E. 5 North Charlotte-street, Edinburgh.
1903. *Milne, R. M. Royal Naval College, Dartmouth, South Devon.
1898. *Milner, S. Roslington, D.Sc. The University, Sheffield.
1908. ‡Milroy, T. H., M.D., Dunville Professor of Physiology in Queen's University, Belfast.
1907. §Milton, J. H., F.G.S., F.L.S., F.R.G.S. 8 College-avenue, Crosby, Liverpool.
1901. *Mitchell, Andrew Acworth. 7 Huntly-gardens, Glasgow.
1913. *Mitchell, Francis W. V. 25 Augustus-road, Edgbaston, Birmingham.

Year of Election.

1901. *Mitchell, G. A. 5 West Regent-street, Glasgow.
1909. ‡Mitchell, J. F. 211 Rupert-street, Winnipeg, Canada.
1885. ‡Mitchell, P. Chalmers, O.B.E., M.A., D.Sc., F.R.S., Sec.Z.S. (Pres. D, 1912; Council, 1906–13.) Zoological Society, Regent's Park, N.W. 1.
1905. *Mitchell, W. E. C. Box 129, Johannesburg.
1908. ‡Mitchell, W. M. 2 St. Stephen's Green, Dublin.
1914. ‡Mitchell, William, M.A., D.Sc., Hughes Professor of Philosophy and Economics in the University of Adelaide, South Australia.
1895. *Moat, William, M.A. Johnson Hall, Eccleshall, Staffordshire.
1905. ‡Moir, James, D.Sc. Mines Department, Johannesburg.
1905. §Molengraaff, Professor G. A. F. Kanaalweg 8, Delft, The Hague.
1883. ‡Mollison, W. L., M.A. Clare College, Cambridge.
1900. *Monckton, H. W., Treas. L.S., F.G.S. 3 Harcourt-buildings, Temple, E.C. 4.
1905. ‡Moncrieff, Lady Scott. 11 Cheyne-walk, S.W. 3.
1919. *Mond, Miss Frida H. Combe Bank, Sundridge.
1919. *Mond, Miss Irene K. Combe Bank, Sundridge.
1891. *Mond, Robert Ludwig, M.A., F.R.S.E., F.G.S. Combe Bank, Sevenoaks.
1915. §Moodie, J. Williams Deacon's Bank, Manchester.
1909. ‡Moody, A. W., M.D. 432½ Main-street, Winnipeg, Canada.
1909. *Moody, G. T., D.Sc. Lorne House, Dulwich, S.E. 21.
1914. §Moody, Mrs. Lorne House, Dulwich, S.E. 21.
1912. §Moore, Benjamin, D.Sc., F.R.S. (Pres. I, 1914.) 14 Frognal, Hampstead, N.W. 3.
1911. §Moore, E. S., Professor of Geology and Mineralogy in the School of Mines, Pennsylvania State College, Pennsylvania, U.S.A.
1908. *Moore, Sir Frederick, M.A., F.L.S. Royal Botanic Gardens, Glasnevin, Dublin.
1894. ‡Moore, Harold E. Oaklands, The Avenue, Beckenham, Kent.
1908. ‡Moore, Sir John W., M.D. 40 Fitzwilliam-square West, Dublin.
1901. *Moore, Robert T. 142 St. Vincent-street, Glasgow.
1905. ‡Moore, T. H. Thornhill Villa, Marsh, Huddersfield.
1916. ‡Moore, Professor T. S. Hillside, Egham, Surrey.
1892. ‡Moray, The Right Hon. the Earl of, F.G.S. Kinfauns Castle, Perth.
1912. ‡Moray, The Countess of. Kinfauns Castle, Perth.
1896. *Mordey, W. M. 82 Victoria-street, S.W. 1.
1901. *Moreno, Francisco P. Paraná 915, Buenos Aires.
1919. §Morey, Frank. Wolverton, Carisbrooke-road, Newport, Isle of Wight.
1905. *Morgan, Miss Annie. Care of London County Westminster and Parr's Bank, Chancery-lane, W.C. 1.
1895. ‡Morgan, C. Lloyd, F.R.S., F.G.S., Professor of Psychology in the University of Bristol.
1902. ‡Morgan, Gilbert T., O.B.E., D.Sc., F.I.C., Professor of Chemistry in the University of Birmingham.
1919. §Morison, C. G. T. School of Rural Economy, Oxford.
1901. *Morison, James. Perth.
1883. *Morley, Henry Forster, M.A., D.Sc., F.C.S. 5 Lyndhurst-road, Hampstead, N.W. 3.
1906. ‡Morrell, H. R. Scarcroft-road, York.
1896. *Morrell, Dr. R. S. Tor Lodge, Tettenhall Wood, Wolverhampton.
1892. ‡Morris, Sir Daniel, K.C.M.G., D.Sc., F.L.S. (Pres. K., 1919; Council, 1915– .) 14 Crabton-close, Boscombe, Hants.

Year of Election.

1915. *Morris, H. N. 10 Norfolk-street, Manchester.
1880. ‡Morris, James. 23 Brynymor-crescent, Swansea.
1907. ‡Morris, Colonel Sir W. G., K.C.M.G. Care of Messrs. Cox & Co., 16 Charing Cross, W.C. 2.
1899. *Morrow, Major John, M.Sc., D.Eng. Armstrong College, Newcastle-upon-Tyne.
1909. ‡Morse, Morton F. Wellington-crescent, Winnipeg, Canada.
1896. *Morton, William B., M.A., Professor of Natural Philosophy in Queen's University, Belfast.
1908. ‡Moss, C. E., D.Sc., Professor of Botany, University College, Johannesburg.
1876. ‡Moss, Richard Jackson, F.I.C., M.R.I.A. Royal Dublin Society, and St. Aubyn's, Ballybrack, Co. Dublin.
1892. *Mostyn, S. G., M.A., M.B. 2 Harewood-hill, Darlington.
1913. ‡Mott, Dr. F. W., F.R.S. 25 Nottingham-place, W. 1.
1919. §Mottram, Allan P. Caterham School, Surrey.
1913. ‡Mottram, V. H. 256 Lordship-lane, East Dulwich, S.E. 22.
1912. *Moulton, J. C., Director of the Raffles Museum and Library, Singapore.
1878. *Moulton, The Right Hon. Lord Justice, G.B.E., K.C.B., M.A., K.C., F.R.S. 57 Onslow-square, S.W. 7.
1905. *Moysey, Miss E. L. Pitcroft, Guildford, Surrey.
1912. ‡Mudie, Robert Francis. 6 Fintry-place, Broughty Ferry.
1902. ‡Muir, Arthur H. 7 Donegall-square West, Belfast.
1907. *Muir, Professor James. 31 Burnbank-gardens, Glasgow.
1915. ‡Muir, Ramsay. 140 Plymouth-grove, Manchester.
1909. ‡Muir, Robert R. Grain Exchange-building, Winnipeg, Canada.
1912. §Muir, Thomas Scott. 19 Seton-place, Edinburgh.
1904. ‡Muir, William, I.S.O. Rowallan, Newton Stewart. N.B.
1872. *Muirhead, Alexander, D.Sc., F.R.S., F.C.S. The Lodge, Shortlands, Kent.
1905. *Muirhead, James M. P., F.R.S.E. The Dunlop Rubber Co., Ltd., Aston Cross, Birmingham.
1876. *Muirhead, Robert Franklin, B.A., D.Sc. 64 Great George-street, Hillhead, Glasgow.
1902. ‡Mullan, James. Castlerock, Co. Derry.
1915. ‡Mullen, B. H., M.A. Salford Museum, Peel Park, Salford.
1904. ‡Mullinger, J. Bass, M.A. 1 Bene't-place, Cambridge.
1911. ‡Mumby, Dr. B. H. Borough Asylum, Milton, Portsmouth.
1898. ‡Mumford, C. E. Cross Roads House, Bouverie-road, Folkestone.
1901. *Munby, Alan E. 44 Downshire-hill, Hampstead, N.W. 3.
1906. ‡*Munby, Frederick J. Whixley, York.*
1904. ‡Munro, A. Queens' College, Cambridge.
1909. ‡Munro, George. 188 Roslyn-road, Winnipeg, Canada.
1883. *Munro, Robert, M.A., M.D., LL.D. (Pres. H, 1893.) Elmbank, Largs, Ayrshire, N.B.
1914. *Murchison, Roderick. Melbourne-mansions, Collins-street, Melbourne.
1909. §Murphy, A. J. Queen-square, Leeds.
1908. ‡Murphy, Leonard. 156 Richmond-road, Dublin.
1908. ‡Murphy, William M., J.P. Dartry, Dublin.
1905 ‡Murray, Charles F. K., M.D. Kenilworth House, Kenilworth, Cape Colony.
1903. §Murray, Colonel J. D. Mytholmroyd, Wigan.
1916. ‡Murray, Miss Jessie, M.B. 14 Endsleigh-street, W.C. 1.
1914. ‡Murray, John. Tullibardin New Farm, Brisbane, Australia.

Year of Election.

1915. ‡Murray, Miss M. A. Edwards Library, University College, Gower-street, W.C. 1.
1892. ‡Murray, T. S., D.Sc. 27 Shamrock-street, Dundee.
1909. ‡Murray, W. C. University of Saskatchewan, Saskatoon, Saskatchewan, Canada.
1919. §Muscio, B., Psychological Laboratory, Cambridge.
1906. ‡Musgrave, Mrs. Edith M. S., D.Sc. 11 Palace-gate, W. 8.
1919. §Musgrave, Captain Stanley. 11 Palace-gate, W. 8.
1912. *Musgrove, James, M.D., Professor of Anatomy in the University of St. Andrews, N.B.
1870. *Muspratt, Edward Knowles. Seaforth Hall, near Liverpool.
1906. ‡Myddelton-Gavey, Major E. H., J.P., F.R.G.S. Care of Captain Alex. de Hamel, Wigginton Lodge, Tamworth, Staffordshire.
1913. ‡Myddelton-Gavey, Miss Violet. Stanton Prior, Meads, Eastbourne.
1902. *Myers, Charles S., M.A., M.D. Great Shelford, Cambridge.
1909. *Myers Henry. Ebbisham Lodge, Downs-avenue, Epsom.
1906. ‡Myers, Jesse A. Glengarth, Walker-road, Harrogate.
1915. ‡Myers, William. 7 Station-road, Cheadle Hulme.
1890. *Myres, John L., M.A., F.S.A. (General Secretary, 1919– ; Pres. H, 1909; Council, 1909–16), Wykeham Professor of Ancient History in the University of Oxford. 101 Banbury-road, Oxford.
1919. *Myres, J. N. L. 101 Banbury-road, Oxford.
1914. *Myres, Miles Claude. 101 Banbury-road, Oxford.

1886. ‡Nagel, D. H., M.A. (Local Sec. 1894.) Trinity College, Oxford.
1890. †*Nalder, Francis Henry.* 34 *Queen-street, E.C.* 4.
1919. §Napper, Sidney S. Upmeads, Dunbar-road, Bournemouth.
1908. *Neal, Mrs. E. M. 10 Meadway, Hampstead Garden Suburb, N.W. 4.
1909. ‡Neild, Frederic, M.D. Mount Pleasant House, Tunbridge Wells.
1883. *Neild, Theodore, M.A. Grange Court, Leominster.
1914. ‡Nelson, Miss Edith A., M.A., M.Sc. 131 Williams-road, East Prahran, Victoria.
1914. *Nettlefold, J. S. Winterbourne, Edgbaston Park-road, Birmingham.
1914. ‡Nettlefold, Miss. Winterbourne, Edgbaston Park-road, Birmingham.
1866. *Nevill, The Right Rev. Samuel Tarratt, D.D., F.L.S., Bishop of Dunedin, New Zealand.
1889. *Newall, H. Frank, M.A., F.R.S., F.R.A.S., Professor of Astrophysics in the University of Cambridge. Madingley Rise, Cambridge.
1912. ‡Newberry, Percy E., M.A., Professor of Egyptology in the University of Liverpool. Oldbury Place, Ightham, Kent.
1916. ‡Newbigin, Henry T. 3 St. Nicholas-buildings, Newcastle-on-Tyne.
1901. ‡Newbigin, Miss Marion, D.Sc. Royal Scottish Geographical Society, Edinburgh.
1919. §Newgass, G. A. Trinity College, Cambridge.
1919. §Newgass, Mrs. Maria R. Shernfold Park, Frant.
1901. ‡Newman, F. H. Tullie House, Carlisle.
1913. ‡Newman, L. F. 2 Warkworth-street, Cambridge.
1889. ‡Newstead, A. H. L., B.A. 38 Green-street, Bethnal Green, E. 2.
1912. **Newton, Arthur U. University College, Gower-street, W.C.* 1.
1892. ‡Newton, E. T., F.R.S., F.G.S. Florence House, Willow Bridge-road, Canonbury, N. 1.

Year of Election.

1914. §Newton, R. Bullen, F.G.S. British Museum (Natural History), South Kensington, S.W. 7.
1914. ‡Nicholls, Dr. E. Brooke. 174 Victoria-street, North Melbourne.
1914. ‡Nicholls, Professor G. E. King's College, Strand, W.C. 2.
1908. ‡Nicholls, W. A. 11 Vernham-road, Plumstead, Kent.
1908. ‡Nichols, Albert Russell. 30 Grosvenor-square, Rathmines, Co. Dublin.
1908. ‡Nicholson, J. W., M.A., D.Sc., F.R.S., Professor of Mathematics in King's College, Strand, W.C. 2.
1884. ‡Nicholson, Joseph S., M.A., D.Sc. (Pres. F, 1893), Professor of Political Economy in the University of Edinburgh.
1911. ‡Nicol, J. C., M.A. The Grammar School, Portsmouth.
1916. ‡Nisbet, E. T. 26 Beverley-gardens, Cullercoats.
1915. ‡Niven, James. Civic Buildings, 1 Mount-street, Manchester.
1908. ‡Nixon, The Right Hon. Sir Christopher, Bart., M.D., LL.D., D.L. 2 Merrion-square, Dublin.
1916. ‡Noble, J. H. B. Sandhoe, Hexham, Northumberland.
1888. ‡Norman, George. 12 Brock-street, Bath.
1913. ‡Norman, Right Hon. Sir Henry, Bart., M.P. The Corner House, Cowley-street, S.W.
1912. ‡Norrie, Robert. University College, Dundee.
1913. ‡Norris, F. Edward. Seismograph Station, Hill View, Woodbridge Hill, Guildford.
1894. §Notcutt, S. A., LL.M., B.A., B.Sc. (Local Sec. 1895.) Constitution-hill, Ipswich.
1909. ‡Nugent, F. S. 81 Notre Dame-avenue, Winnipeg, Canada.
1910. §Nunn, T. Percy, M.A., D.Sc., Professor of Education in the University of London. London Day Training College, Southampton-row, W.C. 1.
1919. §Nuttall, Professor G. H. F., F.R.S. Longfield, Madingley-road, Cambridge.
1915. ‡Nuttall, Harry, M.P. Bank of England-chambers, Manchester.
1913. §Nuttall, T. E., M.D. Middleton, Huncoat, Accrington.
1912. ‡Nuttall, W. H. Cooper Laboratory for Economic Research, Rickmansworth-road, Watford.

1919. §Oaten, Mrs. Elizabeth. Eldon Cottage, Seabourne-road, Bournemouth.
1898. *O'Brien, Neville Forth. Greywell House, Woking.
1908. ‡O'Carroll, Joseph, M.D. 43 Merrion-square East, Dublin.
1913. §Ockenden, Maurice A., F.G.S. Oil Well Supply Company, Dashwood House, New Broad-street, E.C. 2.
1883. ‡Odgers, William Blake, M.A., LL.D., K.C. 15 Old-square, Lincoln's Inn, W.C. 2.
1910. *Odling, Marmaduke, M.A., B.Sc., F.G.S. Lackenby Iron Works, Grangetown, Yorkshire.
1858. *Odling, William, M.B., F.R.S., V.P.C.S. (Pres. B, 1864; Council, 1865–70.) 15 Norham-gardens, Oxford.
1911. *O'Donoghue, Charles H., D.Sc. University College, Gower-street, W.C. 1.
1908. §O'Farrell, Thomas A., J.P. 30 Lansdowne-road, Dublin.
1915. ‡Ogden, C. K., M.A. Magdalene College, Cambridge.
1902. ‡Ogden, James Neal. Claremont, Heaton Chapel, Stockport.
1913. ‡Ogilvie, A. G. 15 Evelyn-gardens, S.W.
1876. ‡Ogilvie, Campbell P. Lawford-place, Manningtree.
1914. ‡Ogilvie, Mrs. Campbell P. Lawford-place, Manningtree.

Year of Election.

1885. ‡Ogilvie, Sir F. Grant, C.B., M.A., B.Sc., F.R.S.E. (Local Sec. 1892). Science Museum, South Kensington, S.W. 7.
1912. ‡Ogilvy, J. W. 18 Bloomsbury-square, W.C. 1.
1905. *Oke, Alfred William, B.A., LL.M., F.G.S., F.L.S. 32 Denmark-villas, Hove, Brighton.
1905. ‡Okell, Samuel, F.R.A.S. Overley, Langham-road, Bowdon, Cheshire.
1919. *Okey, F. J. 26 Portarlington-road, Bournemouth..
1908. §Oldham, Charles Hubert, B.A., B.L., Professor of Commerce in the National University of Ireland. 5 Victoria-terrace, Rathgar, Dublin.
1892. ‡Oldham, H. Yule, M.A., F.R.G.S., Lecturer in Geography in the University of Cambridge. King's College, Cambridge.
1893. *Oldham, R. D., F.R.S., F.G.S. 1 Broomfield-road, Kew, Surrey.
1912. ‡O'Leary, Rev. William, S.J. Belvedere College, Dublin.
1914. ‡Oliver, Calder E. Manor-street, Brighton, Victoria.
1887. ‡Oliver, F. W., D.Sc., F.R.S., F.L.S. (Pres. K, 1906). Professor of Botany in University College, London, W.C. 1.
1914. ‡Oliver, H. G., C.E. Lara, Victoria, Australia.
1889. ‡Oliver, Professor Sir Thomas, M.D. 7 Ellison-place, Newcastle-upon-Tyne.
1882. §Olsen, O. T., D.Sc., F.L.S., F.R.A.S., F.R.G.S. 116 St. Andrew's terrace, Grimsby.
1919. *Omer-Cooper, Joseph. 6 Queensland-road, Bournemouth.
1908. ‡O'Neill, Rev. G., M.A. University College, St. Stephen's Green, Dublin.
1902. ‡O'Neill, Henry, M.D. 6 College-square East, Belfast.
1913. ‡Orange, J. A. General Electric Company, Schenectady, New York, U.S.A.
1919. §Ord, Dr. W. T.. F.G.S. 18 Littledown-road, Bournemouth.
1916. §Orde, Edwin L. Walker Shipyard, Newcastle-on-Tyne.
1884. **Orpen, Rev. T. H., M.A. Mark Ash, Abinger Common, Dorking.*
1901. ‡Orr, Alexander Stewart. 10 Medows-street, Bombay, India.
1909. ‡Orr, John B. Crossacres, Woolton, Liverpool.
1908. *Orr, William. Dungarvan, Co. Waterford.
1904. *Orton, K. J. P., M.A., Ph.D., Professor of Chemistry in University College, Bangor.
1915. §Orwin, C. S. 7 Marston Ferry-road, Oxford.
1910. *Osborn, T. G. B., M.Sc., Professor of Botany in the University of Adelaide, South Australia.
1901. ‡Osborne, Professor W. A., D.Sc. The University, Melbourne.
1908. ‡O'Shaughnessy, T. L. 64 Fitzwilliam-square, Dublin.
1881. *Ottewell, Alfred D. 14 Mill Hill-road, Derby.
1906. ‡Owen, Rev. E. C. St. Peter's School, York.
1903. *Owen, Edwin, M.A. Terra Nova School, Birkdale, Lancashire.
1911. ‡Owens, J. S., M.D., Assoc.M.Inst.C.E. 47 Victoria-street, S.W. 1.
1910. *Oxley, Major A. E., R.A.F., M.A., D.Sc. 1 Park-drive, North End-road, N.W.3.

1909. ‡Pace, F. W. 388 Wellington-crescent, Winnipeg, Canada.
1908. ‡Pack-Beresford, Denis, M.R.I.A. Fenagh House, Bagenalstown, Ireland.
1906. §Page, Carl D. Hotel Monticello, 35 West Sixty-fourth-street New York City, New York, U.S.A.
1903. *Page, Miss Ellen Iva. Turret House, Felpham, Sussex
1883. ‡Page, G. W. Bank House, Fakenham.

Year of Election.

1913. ‡Paget, Sir Richard, Bart. Old Fallings Hall, Wolverhampton.
1911. ‡Paget, Stephen, M.A., F.R.C.S. 21 Ladbroke-square, W. 11.
1912. ‡Pahic, Paul. 45 Rue Notre Dame de Loretta, Place St. Georges, Paris.
1919. §Paine, A. E. W. Welford, Stratford-on-Avon.
1911. ‡Paine, H. Howard. 50 Stow-hill, Newport, Monmouthshire.
1919. §Painter, H. 29 Talbot-road, Bournemouth.
1896. ‡Pallis, Alexander. Tatoi, Aigburth-drive, Liverpool.
1878. *Palmer, Joseph Edward. Royal Societies Club, St. James's-street, S.W. 1.
1919. §Paris, E. Talbot. 14 Waldemar-avenue Mansions, S.W. 6.
1915. *Parker, Dr. A. Gasworks, Uddingston, Lanarkshire.
1904. ‡Parker, E. H., M.A. Thorneycreek, Herschel-road, Cambridge.
1909. §Parker, M. A., B.Sc., F.C.S. (Local Sec. 1909), Professor of Chemistry in the University of Manitoba, Winnipeg, Canada.
1891. ‡Parker, William Newton, Ph.D., F.Z.S., Professor of Biology in University College, Cardiff.
1899. *Parkin, John. The Gill, Brayton, Cumberland.
1905. *Parkin, Thomas. Blaithwaite, Carlisle.
1906. §Parkin, Thomas, M.A., F.L.S., F.Z.S., F.R.G.S. Fairseat, High Wickham, Hastings.
1913. ‡Parry, Edward, M.Inst.C.E. Rossmore, Leamington.
1903. §Parry, Joseph, M.Inst.C.E. Woodbury, Waterloo, near Liverpool.
1908. ‡Parry, W. K., M.Inst.C.E. 6 Charlemont-terrace, Kingstown, Dublin.
1878. ‡Parsons, Hon. Sir C. A., K.C.B., M.A., Sc.D., F.R.S., M.Inst.C.E. (President; Pres. G, 1904.) 1 Upper Brook-street, W. 1.
1904. ‡Parsons, Professor F. G. St. Thomas's Hospital, S.E.
1905. *Parsons, Hon. Geoffrey L. Worting House, Basingstoke, Hants.
1919. *Parsons, Hon. Mrs. Margaret B. Worting House, Basingstoke, Hants.
1898. *Partridge, Miss Josephine M. Pioneer Club, 9 Park-place, St. James's, S.W. 1.
1908. ‡Paterson, M., LL.D. 7 Halton-place, Edinburgh.
1909. ‡Paterson, William. Ottawa, Canada.
1897. ‡Paton, D. Noël, M.D., F.R.S. (Pres. I, 1919), Professor of Physiology in the University of Glasgow.
1883. *Paton, Rev. Henry, M.A. Elmswood, Bonnington-road, Peebles.
1884. *Paton, Hugh. Box 2646, Montreal, Canada.
1913. §Patrick, Joseph A., J.P. Broad-street Corner, Birmingham.
1908. *Patten, C. J., M.A., M.D., Sc.D., Professor of Anatomy in the University of Sheffield.
1913. ‡Patterson, W. Hamilton, M.Sc. The Monksferry Laboratory, Birkenhead.
1913. *Pattin, Harry Cooper, M.A., M.D. King-street House, Norwich.
1920. *Patton, Donald, M.A., B.Sc. Manse Villa, Pollok-road, Shawlands, Glasgow.
1879. *Patzer, F. R. Clayton Lodge, Newcastle, Staffordshire.
1887. *Paxman, James. Standard Iron Works, Colchester.
1887. *Payne, Miss Edith Annie. Hatchlands, Cuckfield, Hayward's Heath.
1914. *Payne, Professor Henry, M.Inst.C.E. The University, Melbourne.
1888. *Paynter, J. B. Hendford Manor, Yeovil.
1876. ‡Peace, G. H., M.Inst.C.E. The Beeches, Charcoal-road, Dunham Massey, Altrincham.
1906. ‡Peace, Miss Gertrude. 39 Westbourne-road, Sheffield.

Year of Election.

1885. ‡Peach, B. N., LL.D., F.R.S., F.R.S.E., F.G.S. (Pres. C, 1912.) Geological Survey Office, George-square, Edinburgh.
1911. §Peake, Harold J. E. Westbrook House, Newbury.
1913. ‡Pear, T. H. 18 Chatham Grove, Withington, Manchester.
1919. §Pearce, Miss E. K., LL.A. Kempston, Chine Crescent-road, Bournemouth.
1886. *Pearce, Mrs. Horace. Collingwood, Manby-road, Malvern.
1886. ‡Pearsall, H. D. Letchworth, Herts.
1883. ‡Pearson, Arthur A., C.M.G. Hillsborough, Heath-road, Petersfield, Hampshire.
1893. *Pearson, Charles E. Hillcrest, Lowdham, Nottinghamshire.
1898. ‡Pearson, George. Bank-chambers, Baldwin-street, Bristol.
1906. ‡Pearson, Dr. Joseph. The Museum, Colombo, Ceylon.
1904. ‡Pearson, Karl, M.A., F.R.S., Professor of Eugenics in the University of London. 7 Well-road, Hampstead, N.W. 3.
1909. ‡Pearson, William. Wellington-crescent, Winnipeg, Canada.
1888. ‡Peckover, Miss Alexandrina. Bank House, Wisbech, Cambridgeshire.
1885. ‡Peddie, William, Ph.D., F.R.S.E., Professor of Natural Philosophy in University College, Dundee.
1884. ‡Peebles, W. E. 9 North Frederick-street, Dublin.
1901. *Peel, Right Hon. Viscount. 52 Grosvenor-street, W. 1.
1905. §Peirson, J. Waldie. P.O. Box 561, Johannesburg.
1915. ‡Pemberton, Granville. 49 Acresfield-road, Pendleton.
1905. ‡Pemberton, Gustavus M. P.O. Box 93, Johannesburg.
1916. ‡Pemberton, J. S. G. Belmont, Durham.
1887. ‡Pendlebury, William H., M.A., F.C.S. (Local Sec. 1899.) Broadlands, Canonbury, Shrewsbury.
1894. ‡Pengelly, Miss. Lamorna, Torquay.
1896. ‡Pennant, P. P. Nantlys, St. Asaph.
1919. §Penrose, Dr. F. G. 44 Westcliff-road, Bournemouth.
1898. ‡Percival, Francis W., M.A., F.R.G.S. 1 Chesham-street, S.W. 1.
1908. ‡Percival, Professor John, M.A. University College, Reading.
1905. ‡Péringuey, L., D.Sc., F.Z.S. South African Museum, Cape Town.
1894. ‡Perkin, A. G., F.R.S., F.R.S.E., F.C.S., F.I.C. Grosvenor Lodge, Grosvenor-road, Leeds.
1902. **Perkin, F. Mollwo, Ph.D.* 199 *Piccadilly, W.* 1.
1884. ‡Perkin, William Henry, LL.D., Ph.D., F.R.S., F.R.S.E. (Pres. B, 1900; Council, 1901–07, 1917–), Waynflete Professor of Chemistry in the University of Oxford. 5 Charlbury-road, Oxford.
1864. *Perkins, V. R. Wotton-under-Edge, Gloucestershire.
1898. *Perman, Professor E. P., D.Sc. University College, Cardiff.
1909. ‡Perry, Rev. Professor E. Guthrie. 246 Kennedy-street, Winnipeg, Canada.
1874. *Perry, Professor John, M.E., D.Sc., LL.D., F.R.S. (General Treasurer, 1904– ; Pres. G, 1902; Pres. L, 1914; Council, 1901–04.) British Association, Burlington House, London, W. 1.
1913. ‡Perry, W. J. 7 York-view, Pocklington, Yorkshire.
1904. *Pertz, Miss D. F. M. 2 Cranmer-road, Cambridge.
1900. *Petavel, Sir J. E., K.B.E., D.Sc., F.R.S. (Pres. G. 1919), Director of the National Physical Observatory. Bushy House, Teddington, Middlesex.
1914. *Peters, Thomas. Burrinjuck viâ Goondah, N.S.W.
1901. ‡Pethybridge, G. H., Ph.D. Royal College of Science, Dublin.

Year of Election.

1910. *Petrescu, Captain Dimitrie, R.A., M.Eng. Scoala Superiora de Messern, Bucharest, Rumania.
1895. ‡Petrie, W. M. Flinders, D.C.L., F.R.S. (Pres. H, 1895), Professor of Egyptology in University College, W.C. 1.
1886. ‡Phelps, Lieut.-General A. 23 Augustus-road, Edgbaston, Birmingham.
1911. ‡Philip, Alexander. Union Bank-buildings, Brechin.
1896. ‡Philip, G. Hornend, Pinner, Middlesex.
1853. *Philips, Rev. Edward. Hollington, Uttoxeter, Staffordshire.
1877. ‡Philips, T. Wishart. Elizabeth Lodge, Crescent-road, South Woodford, Essex.
1905. ‡Phillimore, Miss C. M. Shiplake House, Henley-on-Thames.
1899. *Phillips, Charles E. S., F.R.S.E. 54 Bedford-gardens, W. 8.
1910. *Phillips, P. P., Ph.D., Professor of Chemistry in the Thomason Engineering College, Rurki, United Provinces, India.
1890. ‡Phillips, R. W., M.A., D.Sc., F.L.S., Professor of Botany in University College, Bangor. 2 Snowdon-villas, Bangor.
1909. *Phillips, Richard. 15 Dogpole, Shrewsbury.
1915. ‡Phillips, Captain W. E. 7th Leinster Regiment. Kilworth Camp, Co. Cork.
1901. ‡Pickard, Robert H., D.Sc., F.R.S. Billinge View, Blackburn.
1885. *Pickering, Spencer P. U., M.A., F.R.S. Harpenden, Herts.
1907. ‡Pickles, A. R., M.A. Todmorden-road, Burnley.
1888. *Pidgeon, W. R. Lynsted Lodge, St. Edmund's-terrace, Regent's Park, N.W. 8.
1919. §Pilcher, T. H. London City and Midland Bank, Bournemouth.
1896. *Pilkington, A. C. Briars Hey, Rainhill, Lancashire.
1905. ‡Pilling, Arnold. Royal Observatory, Cape Town.
1905. ‡Pim, Miss Gertrude. Charleville, Blackrock, Co. Dublin.
1911. ‡Pink, H. R. The Mount, Fareham, Hants.
1911. ‡Pink, Mrs. H. R. The Mount, Fareham, Hants.
1911. ‡Pink, Mrs. J. E. The Homestead, Eastern-parade, Southsea.
1908. ‡Pirrie, The Right Hon. Lord, LL.D., M.Inst.C.E. Downshire House, Belgrave-square, S.W. 1.
1909. ‡Pitblado, Isaac, K.C. 91 Balmoral-place, Winnipeg, Canada.
1893. *Pitt, Walter, M.Inst.C.E. South Stoke House, near Bath.
1900. *Platts, Walter. Morningside, Scarborough.
1911. *Plimmer, R. H. A. Ranulf-road, Hampstead, N.W. 2.
1915. §Plummer, Professor H. C., M.A., Royal Astronomer of Ireland. Dunsink Observatory, Co. Dublin.
1898. ‡Plummer, W. E., M.A., F.R.A.S. The Observatory, Bidston, Birkenhead.
1916. ‡Plummer, Sir W. R. 4 Queen's-square, Newcastle-on-Tyne.
1908. ‡Plunkett, Colonel G. T., C.B. Belvedere Lodge, Wimbledon, S.W.
1900. *Pocklington, H. Cabourn, M.A., D.Sc., F.R.S. 5 Wellclose-place, Leeds.
1916. §Pole, Miss H. J. Halfacre Piece, Boar's Hill, Oxford.
1914. ‡Pollock, Professor J. A., D.Sc., F.R.S. The University, Sydney, N.S.W.
1906. *Pontifex, Miss Catherine E. 7 Hurlingham-court, Fulham, S.W. 6.
1891. ‡Pontypridd, Lord. Pen-y-lan, Cardiff.
1907. §Pope, Alfred, F.S.A. South Court, Dorchester.
1919. §Pope, F. G., D.Sc. East London College, Mile End-road, E. 1.
1900. *Pope, Sir W. Jackson, K.B.E., M.A., LL.D., F.R.S. (Pres. B, 1914), Professor of Chemistry in the University of Cambridge. Chemical Laboratory, The University, Cambridge.

Year of Election.

1901. §Porter, Alfred W., B.Sc., F.R.S. 87 Parliament Hill-mansions, Lissenden-gardens, N.W. 5.
1905. §Porter, J. B., D.Sc., M.Inst.C.E., Professor of Mining in the McGill University, Montreal, Canada.
1905. ‡Porter, Mrs. McGill University, Montreal, Canada.
1911. §Porter, Mrs. W. H., M.Sc. Lehenagh House, Cork.
1883. ‡Potter, M. C., M.A., F.L.S., Professor of Botany in the Armstrong College, Newcastle-upon-Tyne. 13 Highbury, Newcastle-upon-Tyne.
1906. ‡Potter-Kirby, Alderman George. Clifton Lawn, York.
1919. *Potts, Arthur J. 247 Hagley-road, Edgbaston, Birmingham.
1907. ‡Potts, F. A. University Museum of Zoology, Cambridge.
1908. *Potts, George, Ph.D., M.Sc. 91 Park-road, Bloemfontein, South Africa.
1886. *Poulton, Edward B., M.A., F.R.S., F.L.S., F.G.S., F.Z.S. (Pres. D, 1896; Council, 1895–1901, 1905–12), Professor of Zoology in the University of Oxford. Wykeham House, Banbury-road, Oxford.
1905. ‡Poulton, Mrs. Wykeham House, Banbury-road, Oxford.
1913. ‡Poulton, Miss. Wykeham House, Banbury-road, Oxford.
1898. *Poulton, Edward Palmer, M.A. Wykeham Cottage, Woldingham, Surrey.
1894. *Powell, Sir Richard Douglas, Bart., M.D. 11B Portland-place, W. 1.
1887. ‡Pownall, George H. 20 Birchin-lane, E.C. 3.
1908. ‡Praeger, R. Lloyd, B.A., M.R.I.A. Lisnamae, Rathgar, Dublin.
1907. *Prain, Lieut.-Col. Sir David, C.I.E., C.M.G., M.B., F.R.S. (Pres. K, 1909; Council, 1907–14.) Royal Botanic Gardens, Kew.
1884. *Prankerd, A. A., D.C.L. 66 Banbury-road, Oxford.
1913. *Prankerd, Miss Theodora Lisle. 25 Hornsey Lane-gardens, N. 6.
1904. §Prentice, Mrs. Manning. 27 Baldock-road, Letchworth.
1892. ‡Prentice, Thomas. Willow Park, Greenock.
1906. ‡Pressly, D. L. Coney-street, York.
1914. ‡Preston, C. Payne. Australian Distillery Co., Byrne-street, South Melbourne.
1914. ‡Preston, Miss E. W. 153 Barry-street, Carlton, Victoria.
1903. §Price, Edward E. Oaklands, Oaklands-road, Bromley, Kent.
1888. ‡Price, L. L. F. R., M.A., F.S.S. (Pres. F, 1895; Council, 1898-1904.) Oriel College, Oxford.
1875. *Price, Rees. Walnuts, Broadway, Worcestershire.
1913. §Price, T. Slater. Municipal Technical School, Suffolk-street, Birmingham.
1897. *Price, W. A., M.A. The Elms; Park-road, Teddington.
1914. ‡Priestley, Professor H. J. Edale, River-terrace, Kangaroo Point, Brisbane, Australia.
1908. §Priestley, J. H., B.Sc., Professor of Botany in the University of Leeds.
1919. *Primrose, Miss Ethel H. Culmore, Deering's-road, Reigate.
1909. *Prince, Professor E. E., LL.D., Dominion Commissioner of Fisheries. 206 O'Connor-street, Ottawa, Canada.
1889. *Pritchard, Eric Law, M.D., M.R.C.S. 70 Fairhazel-gardens, South Hampstead, N.W. 6.
1876. *Pritchard, Urban, M.D., F.R.C.S. 26 Wimpole-street, W. 1.
1881. §Procter, John William. Minster Hill, Huttons Ambo, York.
1884. *Proudfoot, Alexander, M.D. Care of E. C. S. Scholefield, Esq., Provincial Librarian, Victoria, B.C., Canada.
1919. *Proudman, J., M.A., D.Sc. The University, Liverpool.

Year of Election.

1879. *Prouse, Oswald Milton, F.G.S. Alvington, Ilfracombe.
1872. *Pryor, M. Robert. Weston Park, Stevenage, Herts.
1919. §Pugh-Jones, David. 15 Colchester-avenue, Cardiff.
1903. ‡Pullen-Burry, Miss. Lyceum Club, 128 Piccadilly, W. 1.
1920. M Pullman, Arthur. Wonersh, Hathaway-road, Southbourne.
1904. ‡Punnett, R. C., M.A., F.R.S., Professor of Biology in the University of Cambridge. Caius College, Cambridge.
1913. ‡Purser, G. Leslie. The University, Edinburgh.
1913. ‡Purser, John, M.Sc. City and Guilds Engineering College, Exhibition-road, S.W. 7.
1911. ‡Purvis, J. E. Corpus Christi College, Oxford.
1912. ‡Pycraft, Dr. W. P. British Museum (Natural History), Cromwell-road, S.W. 7.
1919. *Pye, David R. Trinity College, Cambridge.
1898. *Pye, Miss E. St. Mary's Hall, Rochester.
1883. §Pye-Smith, Arnold. 32 Queen Victoria-street, E.C. 4.
1883. ‡Pye-Smith, Mrs. 32 Queen Victoria-street, E.C. 4.
1879. ‡Pye-Smith, R. J. 450 Glossop-road, Sheffield.
1911. ‡Pye-Smith, Mrs. R. J. 450 Glossop-road, Sheffield.

1906. *Quiggin, Mrs. A. Hingston. Fitzwilliam House-road, Cambridge.

1879. ‡Radford, R. Heber. 15 St. James's-row, Sheffield.
1911. §Rae, John T. National Temperance League, Paternoster House, Paternoster-row, E.C. 4.
1887. *Ragdale, John Rowland. The Beeches, Stand, near Manchester.
1913. §Railing, Dr. A. H., B.Sc. The General Electric Co., Ltd., Witton, Birmingham.
1898. *Raisin, Miss Catherine A., D.Sc. Bedford College, Regent's Park, N.W. 1.
1896. *Ramage, Hugh, M.A. The Technical Institute, Norwich.
1894. *Rambaut, Arthur A., M.A., D.Sc., F.R.S., F.R.A.S., M.R.I.A. Radcliffe Observatory, Oxford.
1908. ‡Rambaut, Mrs. Radcliffe Observatory, Oxford.
1912. ‡Ramsay, Colonel R. G. Wardlaw. Whitehill, Rosewell, Midlothian.
1883. ‡Ramsay, Lady. Beechcroft, Hazlemere, High Wycombe.
1915. ‡Ramsbottom, J. 61 Ennerdale-road, Richmond, Surrey.
1914. ‡Ramsbottom, J. W. 23 Rosebery-crescent, Newcastle-on-Tyne.
1913. ‡Ramsden, William. Blacker-road, Huddersfield.
1869. *Rance, H. Henniker, LL.D. 32 Duncan-terrace, Islington, N. 1.
1919. §Rankin, W. Munn. 52 Fitzharris-avenue, Bournemouth.
1907. ‡Rankine, A. O., D.Sc. University College, W.C. 1.
1868. *Ransom, Edwin, F.R.G.S. 24 Ashburnham-road, Bedford.
1861. ‡Ransome, Arthur, M.A., M.D., F.R.S. (Local Sec. 1861.) Sunnyhurst, Dean Park, Bournemouth.
1903. ‡Rastall, R. H. Christ's College, Cambridge.
1914. ‡Rathbone, Herbert R. 15 Lord-street, Liverpool.
1892. *Rathbone, Miss May. 24 Dartmouth-row, Greenwich, S.E. 10.
1913. ‡Raw, Frank, B.Sc., F.G.S. The University, Edmund-street, Birmingham.
1908. *Raworth, Alexander. St. John's Manor, Jersey.
1915. ‡Rawson, Christopher. 33 Manley-road, Manchester.
1905. ‡Rawson, Colonel Herbert E., C.B., R.E., F.R.G.S. Home Close, Heronsgate, Herts.

Year of Election.

1919. *Rayleigh, The Right Hon. Lord, M.A., Sc.D., F.R.S., Professor of Physics in the Imperial College of Science and Technology, 69 Cadogan-square, S.W. 1.
1883. *Rayne, Charles A., M.D., M.R.C.S. St. Mary's Gate, Lancaster.
1897. *Rayner, Edwin Hartree, M.A. 40 Gloucester-road, Teddington, Middlesex.
1912. §Rayner, Mabel C., D.Sc. (Mrs. W. Neilson Jones), Padworth, Heathside-crescent, Woking.
1907. ‡Rea, Carleton, B.C.L. 34 Foregate-street, Worcester.
1913. §Read, Carveth, M.A. 73 Kensington Gardens-square, W. 2.
1896. *Read, Sir Charles H., LL.D., F.S.A. (Pres. H, 1899.) British Museum, W.C. 1.
1913. ‡Reade, Charles C. Attorney-General's Office, Adelaide.
1914. ‡Reade, Mrs. C. C. Attorney-General's Office, Adelaide.
1884. ‡Readman, J. B., D.Sc., F.R.S.E. Belmont, Hereford.
1915. ‡Reed, H. A. The Red House, Bowdon.
1916. *Reed, Thomas, F.C.A., F.S.S. 1 High West-street, Gateshead-on-Tyne.
1891. *Reed, Thomas A. Bute Docks, Cardiff.
1894. *Rees, Edmund S. G. Dunscar, Oaken, near Wolverhampton.
1903. ‡Reeves, E. A., F.R.G.S. (Pres. E, 1916.) Hillside, Reigate-road, Reigate.
1911. ‡Reeves, Hon. W. Pember, Ph.D. (Pres. F, 1911.) London School of Economics, Clare Market, W.C. 2.
1906. *Reichel, Sir Harry R., M.A., LL.D., Principal of University College, Bangor. Penrallt, Bangor, North Wales.
1910. *Reid, Alfred, M.B., M.R.C.S. The Cranes, Tooting, S.W.
1901. *Reid, Andrew T. Auchterarder House, Auchterarder, Perthshire.
1904. ‡Reid, Arthur H. 30 Welbeck-street, W. 1.
1881. ‡Reid, Arthur S., M.A., F.G.S. Trinity College, Glenalmond.
1903. *Reid, Mrs. E. M., B.Sc. Pinewood, Milford-on-Sea, Hants.
1892. ‡Reid, E. Waymouth, B.A., M.B., F.R.S., Professor of Physiology in University College, Dundee.
1908. ‡Reid, George Archdall, M.B., C.M., F.R.S.E. 9 Victoria-road South, Southsea.
1901. *Reid, Hugh. Belmont, Springburn, Glasgow.
1901. ‡Reid, John. 7 Park-terrace, Glasgow.
1909. ‡Reid, John Young. 329 Wellington-crescent, Winnipeg, Canada.
1904. ‡Reid, P. J. Marton Moor End, Nunthorpe, R.S.O., Yorkshire.
1912. §Reid, Professor R. W., M.D. 37 Albyn-place, Aberdeen.
1897. ‡Reid, T. Whitehead, M.D. St. George's House, Canterbury.
1892. ‡Reid, Thomas. Municipal Technical School, Birmingham.
1887. *Reid, Walter Francis. Fieldside, Addlestone, Surrey.
1919. *Reilly, Jos., M.A., D.Sc., F.R.C.Sc.I. 1 Gilford-avenue, Sandymount, Dublin.
1912. §Reinheimer, Hermann. 103 King Charles-road, Surbiton.
1875. ‡Reingold, A. W., C.B., M.A., F.R.S. (Council, 1890–95.) Longroom, Stonehouse, Plymouth.
1891. *Rendell, Rev. James Robson, B.A. Whinside, Whalley-road, Accrington.
1903. *Rendle, Dr. A. B., M.A., F.R.S., F.L.S. (Pres. K, 1916.) 28 Holmbush-road, Putney, S.W. 15.
1914. ‡Rennie, Professor E. H., M.A., D.Sc. The University, Adelaide, Australia.
1889. *Rennie, George B. 20 Lowndes-street, S.W. 1.
1906. ‡Rennie, John, D.Sc. Natural History Department, University of Aberdeen.

Year of Election.

1916. §Renouf, Louis P. W., B.A. Bute Laboratory and Museum, Rothesay, Isle of Bute.
1905. *Renton, James Hall. Rowfold Grange, Billingshurst, Sussex.
1912. ‡Rettie, Theodore. 10 Doune-terrace, Edinburgh.
1904. ‡Reunert, Theodore, M.Inst.C.E. P.O. Box 92, Johannesburg.
1912. ‡Rew, Sir R. H., K.C.B. (Pres. M, 1915.) Board of Agriculture and Fisheries, 3 St. James's-square, S.W. 1.
1905. §Reyersbach, Louis. 29–30 Holborn Viaduct, E.C. 1.
1883. *Reynolds, A. H. 271 Lord-street, Southport.
1913. ‡Reynolds, J. H. Low Wood, Harborne, Birmingham.
1900. *Reynolds, Miss K. M. 8 Darnley-road, Notting Hill, W.
1906. ‡Reynolds, S. H., M.A., Sc.D., Professor of Geology in the University of Bristol.
1907. §Reynolds, W. G. Waterhouse. Birstall Holt, near Leicester.
1877. *Riccardi, Dr. Paul, Secretary of the Society of Naturalists. Villa Marzaglia, Modena, Italy.
1905. §Rich, Miss Florence, M.A. Granville School, Granville-road, Leicester.
1906. ‡*Richards, Rev. A. W.* 12 *Bootham-terrace, York.*
1914. ‡Richardson, A. E. V., M.A., B.Sc. Department of Agriculture, Melbourne.
1916. ‡Richardson, E. J. Anster, Grainger Park-road, Newcastle-on-Tyne.
1919. §Richardson, Harry. College of Technology, Manchester.
1912. ‡Richardson, Harry, M.Inst.E.E. Electricity Supply Department, Dudhope Crescent-road, Dundee.
1889. ‡Richardson, Hugh, M.A. The Gables, Elswick-road, Newcastle-on-Tyne.
1884. *Richardson, J. Clarke. Derwen Fawr, Swansea.
1916. ‡Richardson, Lawrence. Stoneham, Beech Grove-road, Newcastle-on-Tyne.
1896. *Richardson, Nelson Moore, B.A., F.E.S. Montevideo, Chickerell, near Weymouth.
1901. *Richardson, Owen Willans, M.A., D.Sc., F.R.S., Wheatstone Professor of Physics in King's College, London, W.C. 2.
1914. *Rideal, Eric K., B.A., Ph.D. 28 Victoria-street, S.W. 1.
1883. *Rideal, Samuel, D.Sc., F.C.S. 28 Victoria-street, S.W. 1.
1911. ‡Ridgeway, Miss A. R. 45 West Cliff, Preston.
1902. §Ridgeway, Sir William, M.A., D.Litt., F.B.A. (Pres. H, 1908), Professor of Archæology in the University of Cambridge. Flendyshe, Fen Ditton, Cambridge.
1913. §Ridler, Miss C. C. Coniston, Hunsdon-road, Torquay.
1894. ‡Ridley, E. P., F.G.S. (Local Sec. 1895.) Burwood, Westerfield-road, Ipswich.
1883. *Rigg, Sir Edward, C.B., I.S.O., M.A. Malvern House, East Cliff, Ramsgate.
1892. ‡Rintoul, D., M.A. Clifton College, Bristol.
1912. §Rintoul, Miss L. J. Lahill, Largo, Fife.
1916. *Rintoul, William. Lauriston, Ardrossan, Ayrshire.
1910. ‡Ripper, William, Professor of Engineering in the University of Sheffield.
1903. *Rivers, W. H. R., M.D., F.R.S. (Pres. H, 1911.) St. John's College, Cambridge.
1913. ‡Rivett, A. C. D., B.A., Ph.D. (General Organising Secretary 1914.) The University of Melbourne, Victoria.
1908. *Roaf, Herbert E., M.D., D.Sc., Professor of Physiology in the University of London. 44 Rotherwick-road, Hendon, N.W. 4.

Year of Election.

1898. *Robb, Alfred A., M.A., Ph.D. Lisnabreeny House, Belfast.
1914. ‡Robb, James Jenkins, M.D. Harlow, 19 Linden-road, Bournville, Birmingham.
1896. ‡Roberts, Thomas J. Ingleside, Park-road, Huyton, near Liverpool.
1913. *Robertson, Andrew, Professor of Mechanical Engineering in the University of Bristol.
1916. §Robertson, G. S., M.Sc., F.C.S. East Anglian Institute of Agriculture, Chelmsford.
1897. ‡Robertson, Professor J. W., C.M.G., LL.D. The Macdonald College, St. Anne de Bellevue, Quebec, Canada.
1919. *Robertson, Sir Robert, K.B.E., D.Sc., F.R.S. 29 Charlton-road, Blackheath, S.E.
1901. *Robertson, Robert, B.Sc., M.Inst.C.E. Carnbooth, Carmunnock, Lanarkshire.
1912. §Robertson, R. A., M.A., B.Sc., F.R.S.E., Lecturer on Botany in the University of St. Andrews.
1913. **Robins, Edward, M.Inst.C.E., F.R.G.S. Lobito, Angola, Portuguese South-West Africa.*
1913. ‡Robinson, A. H., M.D. St. Mary's Infirmary, Highgate Hill, N. 19.
1915. §Robinson, Arthur, Professor of Psychology in the University of Durham. Observatory House, Durham.
1903. ‡*Robinson, G. H.* 1 *Weld-road, Southport.*
1902. ‡Robinson, Herbert C. Holmfield, Aigburth, Liverpool.
1911. ‡Robinson, J. J. 'West Sussex Gazette' Office, Arundel.
1902. ‡Robinson, James, M.A., F.R.G.S. Dulwich College, Dulwich, S.E.
1912. ‡Robinson, James. Care of W. Buckley, Esq., Tynemouth-road, North Shields.
1888. ‡Robinson, John, M.Inst.C.E. 8 Vicarage-terrace, Kendal.
1908. *Robinson, John Gorges, B.A. The Hoo, Windermere.
1910. ‡Robinson, John Hargreaves. Cable Ship 'Norseman,' Western Telegraph Co., Caixa no Correu No. 117, Pernambuco, Brazil.
1919. *Robinson, Mrs. Margaret Stafford. The Willows, Gosforth, Northumberland.
1899. *Robinson, Mark, M.Inst.C.E. Struan, Fassett-road, Kingston-on-Thames.
1914. ‡Robinson, Professor R., D.Sc. The University, Liverpool.
1919. §Robinson, Richard. Pine Cottage, Church Stretton, Shropshire.
1904. ‡Robinson, Theodore R. 25 Campden Hill-gardens, W. 8.
1909. ‡Robinson, Captain W. 264 Roslyn-road, Winnipeg, Canada.
1909. ‡Robinson, Mrs. W. 264 Roslyn-road, Winnipeg, Canada.
1918. *Robinson, Wilfrid, B.Sc., M.Sc., Lecturer in Economic Botany in Victoria University, Manchester.
1919. §Robson, Henry. 21 Meyrick Park-crescent, Bournemouth.
1912. ‡Robson, W. G. 50 Farrington-street, Dundee.
1915. §Roby, Frank Henry. New Croft, Alderley Edge.
1885. *Rodger, Edward. 1 Clairmont-gardens, Glasgow.
1905. ‡Roebuck, William Denison, F.L.S. 259 Hyde Park-road, Leeds.
1908 ‡Rogers, A. G. L. Board of Agriculture and Fisheries, 8 Whitehall-place, S.W. 1.
1913. ‡Rogers, Sir Hallewell. Greville Lodge, Sir Harry's-road, Edgbaston, Birmingham.

Year of Election.

1919. *Rogers, H. S., B.A. The Grammar School, Beverley, Yorks.
1890. *Rogers, L. J., M.A., Professor of Mathematics in the University of Leeds. 6 Hollin-lane, Leeds.
1906. ‡Rogers, Reginald A. P. Trinity College, Dublin.
1909. ‡Rogers, Hon. Robert. Roslyn-road, Winnipeg, Canada.
1884. *Rogers, Walter. Care of Capital and Counties Bank, Falmouth.
1876. ‡Rollit, Sir A. K., LL.D., D.C.L., Litt.D. St. Anne's Hill, near Chertsey-on-Thames, Surrey.
1915. ‡Roper, R. E., M.A. Bedale School, Petersfield.
1905. ‡Rose, Miss G. Mabel. Ashley Lodge, Oxford.
1883. *Rose, J. Holland, Litt.D. Walsingham, Millington-road, Cambridge.
1894. *Rose, Sir T. K., D.Sc., Chemist and Assayer to the Royal Mint. 6 Royal Mint, E. 1.
1905. *Rosedale, Rev. H. G., D.D., F.S.A. 7 Gloucester-street, S.W. 1.
1905. *Rosedale, Rev. W. E., D.D. St. Mary Bolton's Vicarage, South Kensington, S.W. 10.
1900. ‡Rosenhain, Walter, B.A., F.R.S. Warrawee, Coombe-lane, Kingston Hill, Surrey.
1914. ‡Rosenhain, Mrs. Warrawee, Coombe-lane, Kingston Hill, Surrey.
1914. ‡Rosenhain, Miss. Warrawee, Coombe-lane, Kingston Hill, Surrey.
1914. ‡Ross, Alexander David, M.A., D.Sc., F.R.A.S., F.R.S.E., Professor of Mathematics and Physics in the University of Western Australia, Perth, Western Australia.
1909. ‡Ross, D. A. 116 Wellington-crescent, Winnipeg, Canada.
1908. ‡Ross, Sir John, of Bladensburg, K.C.B. Rostrevor House, Rostrevor, Co. Down.
1902. ‡Ross, John Callender. 46 Holland-street, Campden-hill, W. 8.
1915. ‡Ross, Roderick. Edinburgh.
1901. ‡Ross, Colonel Sir Ronald, K.C.B., F.R.S. 36 Harley House, Regent's Park, N.W.
1891. *Roth, H. Ling. Briarfield, Stump Cross, Halifax, Yorkshire.
1911. *Rothschild, Right Hon. Lord, D.Sc., Ph.D., F.R.S. Tring Park, Tring.
1901. *Rottenburg, Paul, LL.D. Care of Messrs. Leister, Bock, & Co., Glasgow.
1899. *Round, J. C., M.R.C.S. 19 Crescent-road, Sydenham Hill, S.E. 26.
1884. *Rouse, M. L., B.A. 2 Exbury-road, Catford, S.E.
1905. ‡*Rousselet, Charles F. Fir Island, Bittacy Hill, Mill Hill, N.W.*
1903. *Rowe, Arthur W., M.B., F.G.S. Shottendane, Margate.
1916. *Rowell, Sir Herbert B., K.B.E. The Manor House, Jesmond, Newcastle-on-Tyne.
1890. ‡Rowley, Walter, M.Inst.C.E., F.S.A. Alderhill, Meanwood Leeds.
1910. ‡Rowse, Arthur A., B.A., B.Sc. 190 Musters-road, West Bridgford, Nottinghamshire.
1919. §Rowson, S. 1 Fawley-road, Hampstead, N.W. 6.
1901. *Rudorf, C. C. G., Ph.D., B.Sc. 52 Cranley-gardens, Muswell Hill, N.10.
1904. ‡Ruhemann, Dr. S., F.R.S. The Elms, Adams-road, Cambridge.
1909. ‡Rumball, Rev. M. C., B.A. Morden, Manitoba, Canada.
1896. *Rundell, T. W., F.R.Met.Soc. Terras Hill, Lostwithiel.
1911. ‡Rundle, Henry, F.R.C.S. 13 Clarence-parade, Southsea.
1912. *Rusk, Robert R., M.A., Ph.D. 4 Barns-crescent, Ayr.
1904. ‡Russell, E. J., O.B.E., D.Sc., F.R.S. (Pres. M, 1916; Council, 1916– .) Rothamsted Experimental Station, Harpenden, Herts.

Year of Election.

1883. *Russell, J. W. 28 Staverton-road, Oxford.
1852. *Russell, Norman Scott. Arts Club, Dover-street, W. 1.
1908. ‡Russell, Robert. 51 Kenilworth-square, Rathgar, Dublin.
1908. ‡Russell, Right Hon. Sir T. W., Bart. Olney, Terenure, Co. Dublin.
1886. ‡Rust, Arthur. Eversleigh, Leicester.
1909. *Rutherford, Hon. Alexander Cameron. Strathcona, Alberta, Canada.
1907. §Rutherford, Sir Ernest, M.A., D.Sc., F.R.S. (Pres. A, 1909; Council, 1914–), Professor, Trinity College, Cambridge.
1914. ‡Rutherford, Lady. Trinity College, Cambridge.
1914. ‡Rutherford, Miss Eileen. Trinity College, Cambridge.
1909. ‡Ruttan, Colonel H. N. Armstrong's Point, Winnipeg, Canada.
1919. §Rutter, Dr. G. H. 22 Poole-road, Bournemouth.
1908. ‡Ryan, Hugh, D.Sc. Omdurman, Orwell Park, Rathgar, Dublin.
1909. ‡Ryan, Thomas. Assiniboine-avenue, Winnipeg, Canada.
1906. *Rymer, Sir Joseph Sykes. The Mount, York.

1903. ‡Sadler, M. E., C.B., LL.D. (Pres. L, 1906), Vice-Chancellor of the University of Leeds. 41 Headingley-lane, Leeds.
1883. ‡Sadler, Robert. 7 Lulworth-road, Birkdale, Southport.
1903. ‡Sagar, J. The Poplars, Savile Park, Halifax.
1914. ‡St. John, J. R. Botanic Gardens, Melbourne.
1919. §Salisbury, Dr. E. J., F.L.S. The Briars, Crosspath, Radlett, Herts.
1873. *Salomons, Sir David, Bart., F.G.S. Broomhill, Tunbridge Wells.
1911. §Sampson, Professor R. A., M.A., F.R.S., Astronomer Royal for Scotland. Royal Observatory, Edinburgh.
1901. ‡Samuel, John S., J.P., F.R.S.E. City Chambers, Glasgow.
1907. *Sand, Dr. Henry J. S. The Sir John Cass Technical Institute, Jewry-street, Aldgate, E.C. 3.
1919. *Sandberg, C. P., M.Inst.E. 40 Grosvenor-mansions, S.W. 1.
1919. §Sanderson, G. Meredith. Broxbourne, Parkstone, Dorset.
1915. *Sandon, Harold. 51 Dartmouth Park-hill, Kentish Town, N.W. 5.
1896. §Saner, John Arthur, M.Inst.C.E. Toolerstone, Sandiway, Cheshire.
1896. ‡Saner, Mrs. Toolerstone, Sandiway, Cheshire.
1915. §Saniter, E. H. Care of Messrs. Steel, Peech, & Tozer, Sheffield.
1903. ‡Sankey, Captain H. R., C.B., R.E., M.Inst.C.E. Palace-chambers, 9 Bridge-street, S.W. 1.
1886. ‡Sankey, Percy E. 44 Russell-square, W.C. 1.
1919. §Sarasasna, Lieut.-Colonel Phra. Care of Messrs. Barrow, Brown & Co., Ltd., Bangkok, Siam.
1907. ‡Sargent, H. C. Fritchley, near Derby.
1914. §Sargent, O. H. P.O. Box 34, York, Western Australia.
1919. §Sassoon, David C. 28 Oxford-street, Manchester.
1903. *Saunders, Miss E. R., F.L.S. (Council, 1914– .) Newnham College, Cambridge.
1887. §Sayce, Rev. A. H., M.A., D.D. (Pres. H, 1887), Professor of Assyriology in the University of Oxford. Queen's College, Oxford.
1906. ‡Sayer, Dr. Ettie. 35 Upper Brook-street, W. 1.
1883. *Scarborough, George. 1 Westfield-terrace, Chapel Allerton, Leeds.
1903. ‡Scarisbrick, Sir Charles, J.P. Scarisbrick Lodge, Southport.
1919. *Scatcherd, Miss F. R. 14 Park-square, N.W.
1919. §Scattergood, Joseph. 92 Richmond Wood-road, Bournemouth.

Year of Election.

1879. *Schafer, Sir E. Sharpey, LL.D., D.Sc., M.D., F.R.S. (President, 1912; General Secretary, 1895–1900; Pres. I, 1894; Council, 1887–93), Professor of Physiology in the University of Edinburgh. Marly Knowe, North Berwick.

1914. ‡Schafer, Lady. Marly Knowe, North Berwick.

1914. ‡Scharff, J. W. Knockranny, Bray, Co. Wicklow.

1888. *Scharff, Robert F., Ph.D., B.Sc., F.L.S., Acting Director of the National Museum, Dublin. Knockranny, Bray, Co. Wicklow.

1905. ‡Schönland, S., Ph.D. Albany Museum, Grahamstown, Cape Colony.

1919. *Schott, Miss H. C. 1 Southern-road, West Southbourne, Bournemouth.

1873. *Schuster, Sir Arthur, Ph.D., F.R.S., F.R.A.S. (President 1915; Pres. A, 1892; Council, 1887–93.) Yeldall, Twyford, Berks.

1883. **Sclater, W. Lutley, M.A., F.Z.S. Odiham Priory, Winchfield.*

1905. ‡*Sclater, Mrs. W. L. Odiham Priory, Winchfield.*

1913. §Scoble, Walter A., B.Sc., A.M.Inst.C.E. The Woolwich Polytechnic, William-street, S.E. 18.

1881. *Scott, Alexander, M.A., D.Sc., F.R.S., F.C.S. 34 Upper Hamilton-terrace, N.W. 8.

1916. §Scott, Alexander, M.A., D.Sc. Central Technical School, Stoke-on-Trent.

1919. §Scott, A. B. B., J.P. (Local Sec. 1919). 9 Wimborne-road, Bournemouth.

1878. *Scott, Arthur William, M.A., Professor of Mathematics and Natural Science in St. David's College, Lampeter.

1889. *Scott, D. H., M.A., LL.D., D.Sc., F.R.S., F.L.S. (General Secretary, 1900–03; Pres. K, 1896.) East Oakley House, Oakley, Hants; and Athenæum Club, Pall Mall, S.W. 1.

1915. ‡Scott, Rev. Canon J. J. 65 Ardwick-green, Manchester.

1902. ‡Scott, William R., D.Phil., Litt.D., LL.D., F.B.A. (Pres. F, 1915; Council, 1916–), Professor of Political Economy in the University of Glasgow. 8 University-gardens, Glasgow.

1895. ‡Scott-Elliot, Professor G. F., M.A., B.Sc., F.L.S. Newton, Dumfries.

1883. ‡Scrivener, Mrs. Haglis House, Wendover.

1890. *Searle, G. F. C., Sc.D., F.R.S. Wyncote, Hills-road, Cambridge.

1906. *See, T. J. J., A.M., Ph.D., F.R.A.S., Professor of Mathematics, U.S. Navy. Naval Observatory, Mare Island, California.

1920. MR Selby, Arthur L., M.A., Professor of Physics in University College, Cardiff.

1914. ‡Selby, H. B. 8 O'Connell-street, Sydney, N.S.W.

1907. §Seligman, Dr. C. G., F.R.S. (Pres. H, 1915), Professor of Ethnology in the University of London. The Mound, Long Crendon, Thame, Oxon.

1911. *Seligman, Mrs. C. G. The Mound, Long Crendon, Thame, Oxon.

1913. §Seligmann, Miss Emma A. 61 Kirklee-road, Kelvinside, Glasgow.

1909. ‡Sellars, H. Lee. 225 Fifth-avenue, New York, U.S.A.

1910. ‡Seton, R. S., B.Sc. The University, Leeds.

1895. *Seton-Karr, H. W. 8 St. Paul's-mansions, Hammersmith, W. 6.

1892. *Seward, A. C., M.A., D.Sc., F.R.S., F.G.S. (Pres. K, 1903; Council, 1901–07; Local Sec. 1904), Master of Downing College, Professor of Botany in the University of Cambridge. The Master's Lodge, Downing College, Cambridge.

1913. ‡Seward, Mrs. The Master's Lodge, Downing College, Cambridge.

Year of Election.

1914. ‡Seward, Miss Phyllis. The Master's Lodge, Downing College, Cambridge.
1899. ‡Seymour, Henry J., B.A., F.G.S., Professor of Geology in the National University of Ireland. Earlsfort-terrace, Dublin.
1891. ‡Shackell, E. W. 191 Newport-road, Cardiff.
1905. *Shackleford, W. C. Barnt Green, Worcestershire.
1902. ‡Shaftesbury, The Right Hon. the Earl of, K.P., K.C.V.O. Belfast Castle, Belfast.
1913. ‡Shakespear, G. A., D.Sc., M.A. 21 Woodland-road, Northfield, Worcestershire.
1901. *Shakespear, Mrs. G. A. 21 Woodland-road, Northfield, Worcestershire.
1906. ‡Shann, Frederick. 6 St. Leonard's, York.
1878. ‡Sharp, David, M.A., M.B., F.R.S., F.L.S. Lawnside, Brockenhurst, Hants.
1904. ‡Sharples, George. 181 Great Cheetham-street West, Higher Broughton, Manchester.
1914. ‡Shaw, A. G. Merton-crescent, Albert Park, Victoria, Australia.
1910. *Shaw, J. J. Sunnyside, Birmingham-road, West Bromwich.
1889. *Shaw, Mrs. M. S., B.Sc. Brookhayes, Exmouth.
1883. *Shaw, Sir Napier, M.A., Sc.D., F.R.S. (Pres. A, 1908; Pres. L, 1919; Council 1895–1900, 1904–07.) 10 Moreton-gardens, South Kensington, S.W. 5.
1883. ‡Shaw, Lady. 10 Moreton-gardens, South Kensington, S.W. 5.
1915. §Shaw, Dr. P. E. University College, Nottingham.
1920. MR Shaxby, Capt. J. H. B.Sc. University College, Cardiff.
1912. ‡Shearer, Dr. C., F.R.S. Clare College, Cambridge.
1900. §Sheppard, Thomas, F.G.S. The Municipal Museum, Hull.
1908. ‡Sheppard, W. F., Sc.D., LL.M. Board of Education, Whitehall, S.W.
1883. ‡Sherlock, David. Rahan Lodge, Tullamore, Dublin.
1883. ‡Sherlock, Mrs. David. Rahan Lodge, Tullamore, Dublin.
1896. ‡Sherrington, C. S., M.D., D.Sc., F.R.S. (Pres. I, 1904; Council, 1907–14), Professor of Physiology in the University of Oxford. 9 Chadlington-road, Oxford.
1888. *Shickle, Rev. C. W., M.A., F.S.A. St. John's Hospital, Bath.
1908. *Shickle, Miss Mabel G. M. 9 Cavendish-crescent, Bath.
1887. *Shipley, Sir Arthur E., G.B.E., M.A., D.Sc., F.R.S. (Pres. D, 1909; Council, 1904–11). Christ's College, Cambridge.
1897. ‡Shore, Dr. Lewis E. St. John's College, Cambridge.
1882. ‡Shore, T. W., M.D., B.Sc., Lecturer on Comparative Anatomy at St. Bartholomew's Hospital. 6 Kingswood-road, Upper Norwood, S.E. 19.
1917. §Shorter, Dr. S. A. The University, Leeds.
1904. *Shrubsall, F. C., M.A., M.D. Public Health Department, L.C.C., 2 Savoy-hill, W.C. 2.
1919. *Shurlock, F. W., B.A., B.Sc. 3 Lime-avenue, Derby.
1910. ‡Shuttleworth, T. E. 5 Park-avenue, Riverdale-road, Sheffield.
1889. ‡Sibley, Walter K., M.A., M.D. 6 Cavendish-place, W. 1.
1920. MR Silby, Principal T. Frankland, D.Sc. University College, Swansea.
1902. ‡Siddons, A. W., M.A. Harrow-on-the-Hill, Middlesex.
1883. *Sidebotham, Edward John. Erlesdene, Bowdon, Cheshire.
1877. *Sidebotham, Joseph Watson. Merlewood, Bowdon, Cheshire.
1914. *Sidgwick, Mrs. Henry (Pres. L, 1915). 27 Grange-road, Cambridge.
1913. *Sidgwick, N. V., M.A., D.Sc. Lincoln College, Oxford.

Year of Election.

1873. *Siemens, Alexander, M.Inst.C.E. Palace Place-mansions, Kensington Court, W. 8.
1905. ‡Siemens, Mrs. A. Palace Place-mansions, Kensington Court, W. 8.
1903. *Silberrad, Dr. Oswald. Buckhurst Hill, Essex.
1915. *Simon, Councillor E. D. (Local Sec., 1915.) 20 Mount-street, Manchester.
1914. *Simpson, Dr. G. C., F.R.S. Meteorological Department, Simla, India.
1863. ‡Simpson, J. B., F.G.S. Hedgefield House, Blaydon-on-Tyne.
1909. ‡Simpson, Professor J. C. McGill University, Montreal, Canada.
1913. *Simpson, J. J., M.A., D.Sc. 62 Academy-street, Elgin.
1901. *Simpson, Professor J. Y., M.A., D.Sc., F.R.S.E. 25 Chester-street, Edinburgh.
1907. ‡Simpson, Lieut.-Colonel R. J. S., C.M.G. 66 Shooter's Hill-road, Blackheath, S.E. 3.
1909. *Simpson, Samuel, B.Sc. Box No. 53, Kampala, Uganda.
1909. ‡Simpson, Sutherland, M.D. Cornell University Medical College, Ithaca, New York, U.S.A.
1884. *Simpson, Professor W. J. R., C.M.G., M.D. 31 York-terrace, Regent's Park, N.W. 1.
1909. ‡Sinclair, J. D. 77 Spence-street, Winnipeg.
1912. ‡Sinclair, Sir John R. G., Bart., D.S.O. Barrock House, Wick, N.B.
1907. *Sircar, Dr. Amrita Lal, L.M.S., F.C.S. 51 Sankaritola, Calcutta.
1905. *Sjögren, Professor H. Natural History Museum, Stockholm, Sweden.
1914. *Skeats, E. W., D.Sc., F.G.S., Professor of Geology in the University, Melbourne.
1902. ‡*Skeffington, J. B., M.A., LL.D. Waterford.*
1906. ‡Skerry, H. A. St. Paul's-square, York.
1883. ‡Skillicorne, W. N. 9 Queen's-parade, Cheltenham.
1919. *Skinner, Arthur. 92 Northumberland-park, N.17.
1910. ‡Skinner, J. C. 76 Ivy Park-road, Sheffield.
1916. ‡Skinner, Leslie S. Bill Quay Shipyard, Bill Quay-on-Tyne.
1898. ‡Skinner, Sidney, M.A. (Local Sec. 1904.) South-Western Polytechnic, Manresa-road, Chelsea, S.W.
1905. *Skyrme, C. G. Baltimore, 6 Grange-road, Upper Norwood, S.E.
1913. *Skyrme, Mrs. C. G. Baltimore, 6 Grange-road, Upper Norwood, S.E.
1913. *Slade, R. E., D.Sc. University College, Gower-street, W.C. 1.
1915. ‡Slater, Gilbert. Ruskin College, Oxford.
1919. *Slater, Miss J. M. W., D.Sc. Newnham College, Cambridge.
1916. ‡Small, James. Armstrong College, Newcastle-on-Tyne.
1915. *Smalley, J. Norton Grange, Castleton, Manchester.
1915. §Smalley, William. Springfield, Castleton, Manchester.
1903. *Smallman, Raleigh S. Eliot Lodge, Albemarle-road, Beckenham.
1902. ‡Smedley-Macbean, Mrs. Ida. 68 Overstrand-mansions, Battersea Park, S.W.
1911. ‡Smiles, Professor Samuel, O.B.E., D.Sc., The Quarry, Sanderstead-road, Sanderstead, Surrey.
1911. §Smith, A. Malins, M.A. St. Audrey's Mill House, Thetford, Norfolk.
1914. ‡Smith, Professor A. Micah. School of Mines, Ballarat, Victoria.
1892. ‡Smith, Alexander, B.Sc., Ph.D., F.R.S.E. Department of Chemistry, Columbia University, New York, U.S.A.
1908. ‡Smith, Alfred. 30 Merrion-square, Dublin.
1897. ‡Smith, Andrew, Principal of the Veterinary College, Toronto, Canada.
1901. *Smith, Miss Annie Lorrain. 20 Talgarth-road, West Kensington, W. 14.

Year of Election.

1914. ‡Smith, Arthur Elliot. 4 Willow Bank, Fallowfield, Manchester.
1889. *Smith, Professor C. Michie, C.I.E., B.Sc., F.R.S.E., F.R.A.S., Winsford, Kodaikanal, South India.
1910. ‡Smith, Charles. 11 Winter-street, Sheffield.
1900. ‡Smith, E. J. Grange House, Westgate Hill, Bradford.
1913. *Smith, Miss E. M. 40 Owlstone-road, Newnham, Cambridge.
1908. ‡Smith, E. Shrapnell. 7 Rosebery-avenue, E.C. 1.
1915. ‡Smith, E. W. Fraser. (Local Sec. 1916.) 2 Jesmond-gardens, Newcastle-on-Tyne.
1886. *Smith, Mrs. Emma. Hencotes House, Hexham.
1901. §Smith, F. B. Care of A. Croxton Smith, Esq., Burlington House, Wandle-road, Upper Tooting, S.W. 17.
1911. †Smith, F. E., O.B.E. National Physical Laboratory, Teddington, Middlesex.
1912. ‡Smith, Rev. Frederick. 10 Mayo-road, Sherwood Rise, Nottingham.
1897. ‡Smith, G. Elliot, M.D., F.R.S. (Pres. H, 1912), Professor of Anatomy in University College, London, W.C.
1914. ‡Smith, Mrs. G. Elliot. 4 Willow Bank, Fallowfield, Manchester.
1903. *Smith, Professor H. B. Lees, M.A. The University, Bristol.
1910. §Smith, H. Bompas, M.A. Victoria University, Manchester.
1914. ‡Smith, H. G. Technological Museum, Sydney, N.S.W.
1889. *Smith, Sir H. Llewellyn, G.C.B., M.A., B.Sc., F.S.S. (Pres. F, 1910.) Board of Trade, S.W. 1.
1919. *Smith, Professor J. G. The University, Birmingham.
1860. *Smith, Heywood, M.A., M.D. 30 York-avenue, Hove.
1876. *Smith, J. Guthrie. 5 Kirklee-gardens, Kelvinside, Glasgow.
1902. ‡Smith, J. Lorrain, M.D., F.R.S., Professor of Pathology in the University of Edinburgh.
1903. *Smith, James. Pinewood, Crathes, Aberdeen.
1915. §Smith, Joseph. 28 Altom-street, Blackburn.
1914. ‡Smith, Miss L. Winsford, Kodaikanal, South India.
1914. ‡Smith, Latimer Elliot. 4 Willow Bank, Fallowfield, Manchester.
1910. ‡Smith, Samuel. Central Library, Sheffield.
1913. ‡Smith, Walter Campbell. British Museum (Natural History), Cromwell-road, S.W. 7.
1910. ‡Smith, W. G., B.Sc., Ph.D. College of Agriculture, Edinburgh.
1896. *Smith, Rev. W. Hodson. 104–122 City-road, E.C. 1
1911. ‡Smith, W. Parnell. The Grammar School, Portsmouth.
1885. *Smith, Watson. 34 Upper Park-road, Haverstock Hill, N.W. 3.
1883. ‡Smithells, Arthur, B.Sc., F.R.S. (Pres. B, 1907 ; Local Sec. 1890), Professor of Chemistry in the University of Leeds.
1909. ‡Smylie, Hugh. 13 Donegall-square North, Belfast.
1914. ‡Smyth, John, M.A., Ph.D. Teachers' College, Carlton, Victoria.
1919. §Smyth, W. Johnson, M.D. Perleright, Bournemouth.
1908. §Smythe, J. A., Ph.D., D.Sc. 10 Queen's-gardens, Benton, Newcastle-on-Tyne.
1888. *Snape, H. Lloyd, O.B.E., D.Sc., Ph.D. Fernlea, Mill-lane, Torquay.
1913. *Snell, Sir John, M.Inst.C.E. 8 Queen Anne's-gate, S.W. 1.
1919. ‡Soames, Rev. H. A., M.A., F.Z.S. Hazelcroft, Tiger-lane, Mason's-hill, Bromley.
1905. ‡Soddy, F., M.A., F.R.S.
1905. ‡Sollas, Miss I. B. J., B.Sc. Newnham College, Cambridge.
1879. *Sollas, W. J., M.A., Sc.D., F.R.S., F.R.S.E., F.G.S. (Pres. C, 1900 ; Council, 1900–03), Professor of Geology in the University of Oxford. 48 Woodstock-road, Oxford.

Year of Election.

1883. ‡Sollas, Mrs. 48 Woodstock-road, Oxford.
1915. ‡Somers, Edward. 4 Leaf-square, Pendleton.
1900 *Somerville, W., D.Sc., F.L.S., (Pres. M., 1919), Sibthorpian Professor of Rural Economy in the University of Oxford. 121 Banbury-road, Oxford.
1916. §Soulby, Rev. C. F. H., M.A. 7 Victoria-road, Waterloo, Liverpool.
1919. §Sowerbutts, T. W. Manchester Geographical Society, 16 St. Mary's Parsonage, Manchester.
1883. ‡Spanton, W. D. Ripon Lodge, Hastings.
1913. §Sparke, Thomas Sparrow. Inglefield, Riley-avenue, St. Anne's-on-Sea.
1909. ‡Sparling, Rev. J. W., D.D. 159 Kennedy-street, Winnipeg, Canada.
1893. *Speak, John. Kirton Grange, Kirton, near Boston.
1910. ‡Spearman, C. Birnam, Guernsey.
1912. ‡Speers, Adam, B.Sc., J.P. Holywood, Belfast.
1914. ‡Spencer, Professor Sir W. Baldwin, K.C.M.G., M.A., D.Sc., F.R.S. The University, Melbourne.
1919. §Spencer, W. K., M.A., D.Sc. The Gables, Constable-road, Ipswich.
1910. ‡Spicer, Rev. E. C. Heckfield Vicarage, Winchfield, Hants.
1894. ‡Spiers, A. H. Huntercombe, 51 The Avenue, St. Margaret's-on-Thames.
1864. *Spiller, John, F.C.S. 2 St. Mary's-road, Canonbury, N. 1.
1909. ‡Sprague, D. E. 76 Edmonton-street, Winnipeg, Canada.
1854. *Sprague, Thomas Bond, M.A., LL.D., F.R.S.E. West Holme, Woldingham, Surrey.
1915. ‡Squier, George Owen. 43 Park-lane, W. 1.
1888. *Stacy, J. Sargeant. 152 Shoreditch, E. 1.
1919. *Stamp, L. Dudley. King's College, W.C. 2.
1914. *Stanley, Hon. Sir Arthur, K.C.M.G. State Government House, Melbourne.
1894. *Stansfield, Alfred, D.Sc., Professor of Metallurgy in McGill University, Montreal, Canada.
1909. ‡Stansfield, Edgar. Mines Branch, Department of Mines, Ottawa, Canada.
1900. *Stansfield, Professor H., D.Sc. Hartley University College, Southampton.
1913. §Stanton, T. E., C.B.E., D.Sc., F.R.S. National Physical Laboratory, Teddington, Middlesex.
1911. ‡Stapf, Dr. Otto, F.R.S. Royal Gardens, Kew.
1915. ‡Stapledon, R. G. The Faugan, Llanbadarn, Aberystwyth.
1899. ‡Starling, E. H., M.D., F.R.S. (Pres. I. 1909; Council, 1914–), Professor of Physiology in University College, London, W.C. 1.
1898. ‡Stather, J. W., F.G.S. Brookside, Newland Park, Hull.
1907. §Staynes, Frank. 36–38 Silver-street, Leicester.
1900. *Stead, J. E., D.Sc., F.R.S. (Pres. B, 1910.) 11 Queen's-terrace, Middlesbrough.
1881. ‡Stead, W. H. Beech-road, Reigate.
1892. *Stebbing, Rev. Thomas R. R., M.A., F.R.S. Ephraim Lodge, The Common, Tunbridge Wells.
1896. *Stebbing, W. P. D., F.G.S. Frith Park, Walton Heath, Surrey.
1919. §Steel, Edgar. Hinton Court, Groves-road, Bournemouth.
1914. ‡Steele, Professor B. D., F.R.S. The University, Brisbane, Australia.
1911. ‡Steele, L. J., M.I.E.E. H.M. Dockyard, Portsmouth.
1908. ‡Steele, Lawrence Edward, M.A., M.R.I.A. 18 Crosthwaite-park East, Kingstown, Co. Dublin.

Year of Election.

1912. §Steggall, J. E. A., M.A., F.R.S.E., Professor of Mathematics in University College, Dundee. Woodend, Perth-road, Dundee.
1911. ‡Stein, Sir Marc Aurel, K.C.I.E., D.Sc., D.Litt. Merton College, Oxford
1909. ‡Steinkopj, Max. 667 Main-street, Winnipeg, Canada.
1920. MR Stephens, Lt.-Col. H. F., R.E. Tonbridge, Kent.
1915. §Stephens, Sir William. 2 Cathedral-street, Manchester.
1902. ‡Stephenson, G. Grianan, Glasnevin, Dublin.
1910. *Stephenson, H. K. Banner Cross Hall, Sheffield.
1911. ‡Stern, Moritz. 241 Bristol-road, Birmingham.
1909. ‡Stethern, G. A. Fort Frances, Ontario, Canada.
1908. *Steven, Alfred Ingram, M.A., B.Sc. 16 Great Clyde-street, Glasgow.
1906. ‡Stevens, Miss C. O. The Plain, Foxcombe Hill, Oxford.
1900. ‡Stevens, Frederick. (Local Sec. 1900.) Town Clerk's Office, Bradford.
1880. *Stevens, J. Edward, LL.B. Le Mayals, Blackpyl, R.S.O.
1915. ‡Stevens, Marshall. Trafford Hall, Manchester.
1916. ‡Stevenson, Miss Elizabeth Frances. 24 Brandling-park, Newcastle-on-Tyne.
1916. ‡Stewart, A. W., D.Sc. 3 Annfield-road, Partick Hill, Glasgow.
1909. ‡Stewart, David A., M.D. 407 Pritchard-avenue, Winnipeg, Canada.
1920. MR Stewart, Lt.-Col. F. H. M.D., D.Sc. Glenlea, Hindhead, Surrey.
1875. *Stewart, James, B.A., F.R.C.P.Ed. Junior Constitutional Club, Piccadilly, W. 1.
1901 *Stewart, John Joseph, M.A., B.Sc. 6 Gordon-place, W.C.
1901. *Stewart ,Thomas, M.Inst.C.E. St. George's-chambers, Cape Town.
1915. ‡Stewart, Walter. Ventnor Street Works, Bradford.
1911. ‡Stibbs, H. A. Portsea Island Gas Company, Commercial-road, Portsmouth.
1913. *Stiles, Walter, M.A., Professor of Botany in University College, Reading.
1914. ‡Stillwell, J. L., M.Sc. University of Adelaide, South Australia.
1914. ‡Stirling, Miss A. M. Care of Messrs. Elder & Co., 7 St. Helen's-place, Bishopsgate, E.C. 3.
1876. ‡Stirling, William, M.D., D.Sc., F.R.S.E., Professor of Physiology in the Victoria University, Manchester.
1904. ‡Stobbs, J. T. Dunelm, Basford Park, Stoke-on-Trent.
1906. *Stobo, Mrs. Annie. Somerset House, Garelochhead, Dumbartonshire, N.B.
1901. *Stobo, Thomas. Somerset House, Garelochhead, Dumbartonshire, N.B.
1883. *Stocker, W. N., M.A. Brasenose College, Oxford.
1898. *Stokes, Professor George J., M.A. 5 Fernhurst-villas, College-road, Cork.
1899. *Stone, Rev. F. J. Radley College, Abingdon.
1905. ‡Stoneman, Miss Bertha, D.Sc. Huguenot College, Wellington, Cape Province.
1895. *Stoney, Miss Edith A. 20 Reynolds-close, Hampstead Way, N.W.4.
1908. *Stoney, Miss Florence A., M.D. 4 Nottingham-place, W. 1.
1878. *Stoney, G. Gerald, F.R.S. (Pres. G, 1916), Professor of Mechanical Engineering in the University and in the School of Technology, Manchester.
1883. ‡Stopes, Mrs. 4 Kemplay-road, Hampstead, N.W. 3.

Year of Election.

1903. *Stopes, Marie C., D.Sc., Ph.D., F.L.S. Craigvara, Belmont-road, Leatherhead.
1915. ‡Stopford, John S. B. Woodbank, Higher Fence-road, Macclesfield.
1910. ‡Storey, Gilbert. Department of Agriculture, Cairo.
1887. *Storey, H. L. Bailrigg, Lancaster.
1888. *Stothert, Sir Percy K., K.B.E. 1 Lansdown-place, West Bath.
1905. *Stott, Clement H., F.G.S. P.O. Box 7, Pietermaritzburg, Natal.
1881. ‡Strahan, Sir Aubrey, K.B.E., M.A., Sc.D., F.R.S., F.G.S. (Pres. C, 1904; Council, 1916–), Director of the Geological Survey of Great Britain. Geological Museum, Jermyn-street, S.W. 1.
1905. ‡Strange, Harold F. P.O. Box 2527, Johannesburg.
1908. *Stratton, F. J. M., D.Sc., M.A. Gonville and Caius College, Cambridge.
1914. ‡Street, Mr. Justice. Judges' Chambers, Supreme Court, Sydney, N.S.W.
1906. *Stromeyer, C. E., O.B.E. 9 Mount street, Albert-square, Manchester.
1883. ‡Strong, Henry J., M.D. Colonnade House, The Steyne, Worthing.
1898. *Strong, W. M., M.D. Port Moresby, Papua, via Australia.
1887. *Stroud, H., M.A., D.Sc., Professor of Physics in the Armstrong College, Newcastle-upon-Tyne.
1887. *Stroud, William, D.Sc. Care of Messrs. Barr & Stroud, Anniesland, Glasgow.
1876. *Stuart, Charles Maddock, M.A. St. Dunstan's College, Catford, S.E.
1909. ‡Stupart, Sir Frederic. Meterological Service, Toronto, Canada.
1879. *Styring, Robert. Brinkcliffe Tower, Sheffield.
1891. *Sudborough, Professor J. J., Ph.D., D.Sc., F.I.C. Indian Institute of Science, Bangalore, India.
1902. §Sully, H. T. Scottish Widows-buildings, Bristol.
1911. ‡Summers, A. H., M.A. 16 St. Andrew's-road, Southsea.
1887. *Sumpner, W. E., D.Sc. Technical School, Suffolk-street, Birmingham.
1919. §Sutcliffe, G. E. 113 West Side, Clapham Common, S.W.
1908. ‡Sutherland, Alexander. School House, Gersa, Watten, Caithness.
1919. *Sutherland, G. K., M.A., D.Sc. Professor of Botany in University College, Southampton.
1913. §Sutton, A. W. Winkfield Lodge, Wimbledon Common, S.W.
1914. ‡*Sutton, Harvey, M.D., B.Sc. Trinity College, Parkville, Victoria.*
1911. §Sutton, Leonard, F.L.S. Hillside, Reading.
1911. ‡Sutton, W. L., F.I.C. Hillcroft, Eaton, Norwich.
1905. ‡Swan, Miss Mary E. Overhill, Warlingham, Surrey.
1911. *Swann, Dr. W. F. G., Professor of Physics in the University of Minnesota, Minneapolis, U.S.A.
1897. ‡Swanston, William, F.G.S. Mount Collyer Factory, Belfast.
1914. §Sweet, George, F.G.S. The Close, Brunswick, Victoria, Australia.
1914. ‡Sweet, Miss Georgina, D.Sc. The Close, Brunswick, Victoria, Australia.
1913. ‡Swift, Richard H. 4839 St. Lawrence-avenue, Chicago.
1914. ‡Swinburne, Hon. George. 139 Collins-street, Melbourne
1887. §Swinburne, James, F.R.S., M.Inst.C.E. 82 Victoria-street, S.W. 1.
1913. ‡Swinnerton, H. H. 441 Mansfield-road, Nottingham.
1902. *Sykes, Miss Ella C. Elcombs, Lyndhurst, Hampshire.
1913. ‡Sykes, Godfrey G. Fairlight, Grosvenor-road, Wallington.
1896. *Sykes, Mark L., F.R.M.S. 19 Westbourne-grove, Scarborough.
1902. *Sykes, Major P. Molesworth, C.M.G. Elcombs, Lyndhurst, Hampshire.

Year of Election.

1906. ‡Sykes, T. P., M.A. 4 Gathorne-street, Great Horton, Bradford.
1914. ‡Syme, Mrs. D. York. Balwyn, Victoria.
1903. §Symington, Howard W. Brooklands, Market Harborough.
1885. ‡Symington, Johnson, M.D., F.R.S., F.R.S.E. (Pres. H, 1903). Professor of Anatomy in Queen's University, Belfast.
1914. ‡Symington, Miss N. Queen's University, Belfast.
1908. ‡Synnott, Nicholas J. Furness, Naas, Co. Kildare.

1910. *Tait, John, M.D., D.Sc. 44 Viewforth-terrace, Edinburgh.
1916. ‡Talbot, John. 4 Brandling-park, Newcastle-on-Tyne.
1912. ‡Talbot, P. Amaury. Abbots Morton, Inkberrow, Worcestershire.
1904. §Tallack, H. T. Rocklands, Fairfield-road, Croydon.
1913. ‡Tangye, William. Westmere, Edgbaston Park-road, Birmingham.
1903. *Tanner, Miss Ellen G. 8 Cavendish-place, Bath.
1892. *Tansley, Arthur G., M.A., F.R.S. Grantchester, near Cambridge.
1908. ‡Tarleton, Francis A., LL.D. 24 Upper Leeson-street, Dublin.
1902. ‡Tate, Miss. Rantalard, Whitehouse, Belfast.
1913. §Tattersall, W. M., D.Sc. The Museum, The University, Manchester.
1914. *Taylor, C. Z. Rolyat, 407 Lizar-street, Ballarat, Victoria, Australia.
1887. ‡Taylor, G. H. Holly House, 235 Eccles New-road, Salford.
1906. ‡Taylor, H. Dennis. Stancliffe, Mount-villas, York.
1884. *Taylor, H. M., M.A., F.R.S. Trinity College, Cambridge.
1882. *Taylor, Herbert Owen, M.D. Oxford-street, Nottingham.
1914. ‡Taylor, J. M., M.A. Public Service Board, 4 O'Connell-street, Sydney, N.S.W.
1913. ‡Taylor, J. S. The Corinthians, Warwick-road, Acock's Green.
1915. §Taylor, J. W., D.Sc. Skipton-street, Morecambe.
1860. *Taylor, John, M.Inst.C.E. 6 Queen Street-place, E.C. 4.
1894. *Taylor, W. W., M.A. 66 St. John's-road, Oxford.
1901. *Teacher, John H., M.B. 32 Kingsborough-gardens, Glasgow.
1919. *Teale, E. O., D.Sc., F.G.S. 84 Worple-road, Wimbledon, S.W. 19.
1858. ‡Teale, Thomas Pridgin, M.A., F.R.S. 38 Cookridge-street, Leeds.
1885. ‡Teall, Sir J. J. H., M.A., D.Sc., F.R.S., F.G.S. (Pres. C, 1893; Council, 1894–1900, 1909–16.) Athenæum Club, S.W. 1.
1906. *Teape, Rev. W. M., M.A. South Hylton Vicarage, Sunderland.
1879. ‡Temple, Lieutenant G. T., R.N., F.R.G.S. Solheim, Cumberland Park, Acton, W.
1913. §Temple, Sir R. C., Bart., C.B., C.I.E. (Pres. H, 1913.) The Nash, Worcester.
1916. *Temple, Rev. W., M.A. (Pres. L., 1916.) 20 Melbury-road, Kensington, W. 14.
1892. *Tesla, Nikola. 45 West 27th-street, New York, U.S.A.
1883. ‡Tetley, C. F. The Brewery, Leeds.
1883. ‡Tetley, Mrs. C. F. The Brewery, Leeds.
1882. *Thane, Sir George Dancer, LL.D., Professor of Anatomy in University College, London, W.C. 1. 19 St. John's-road, Harrow.
1919. §Theyser, Dr. A. C. Sleaford, Penn Hill-avenue, Parkstone.
1915. ‡Thewlis, J. Herbert. Daisy Mount, Victoria Park, Manchester.
1906. *Thoday, D., M.A. The University, Manchester.
1906. *Thoday, Mrs. M. G. 6 Lyme-park, Chinley, Stockport.
1870. ‡Thom, Colonel Robert Wilson, J.P. Brooklands, Lord-street West, Southport.

Year of Election.

1914. *Thomas, A., J.P. Brynglas, West Maitland, New South Wales, Australia.
1891. *Thomas, Miss Clara. Pencerrig, Builth.
1919. §Thomas, Major E. R. The School, Rugby.
1903. *Thomas, Miss Ethel N., D.Sc. National Museum of Wales, Cardiff.
1913. ‡Thomas, H. H., M.A., B.Sc., F.G.S. 28 Jermyn-street, S.W. 1.
1910. *Thomas, H. Hamshaw. Botany School, Cambridge.
1899. *Thomas, Mrs. J. W. Holne, near Ashburton, Devon.
1902. *Thomas, Miss M. Beatrice. Girton College, Cambridge.
1904. *Thomas, William, F.R.G.S. Bryn-heulog, Merthyr Tydfil.
1891. *Thompson, Beeby, F.C.S., F.G.S. 67 Victoria-road, Northampton.
1888. *Thompson, Claude M., M.A., D.Sc., Professor of Chemistry in University College, Cardiff. 38 Park-place, Cardiff.
1885. ‡Thompson, D'Arcy W., C.B., B.A., F.R.S. (Pres. D., 1911; Local Sec. 1912), Professor of Natural History in the University of St. Andrews.
1896. *Thompson, Edward P. Paulsmoss, Whitchurch, Salop.
1907. *Thompson, Edwin. Woodlands, 13 Fulwood-park, Liverpool.
1883. *Thompson, Francis. Eversley, Haling Park-road, Croydon.
1904. **Thompson, G. R., B.Sc., Principal of and Professor of Mining in the South African School of Mines, Johannesburg.*
1912. *Thompson, Rev. H. Percy. Hayes Rectory, Kent.
1893. *Thompson, Harry J., M.Inst.C.E. Tregarthen, Garland's-road, Leatherhead.
1920. MR Thompson, Herbert M. Whitley Batch, Llandaff, Cardiff.
1920. M Thompson, Mrs. Whitley Batch, Llandaff, Cardiff.
1919. *Thompson, John McLean, M.A., D.Sc., F.L.S., F.R.S.E. 2 Second-avenue, Cathcart, Glasgow.
1913. *Thompson, Mrs. Lilian Gilchrist. Hayes Rectory, Kent.
1913. ‡Thompson, Peter. 14 Rotten Park-road, Edgbaston, Birmingham.
1876. *Thompson, Richard. Dringcote, The Mount, York.
1913. *Thompson, Sidney Gilchrist. Hayes Rectory, Kent.
1883. *Thompson, T. H. Oldfield Lodge, Gray-road, Bowdon, Cheshire.
1911. ‡Thompson, Mrs. W. H. 328 Assiniboine-avenue, Winnipeg.
1912. ‡Thompson, William Bruce. Thornbank, Dundee.
1912. §Thoms, Alexander. 7 Playfair-terrace, St. Andrews.
1894. ‡Thomson, Arthur, M.A., M.D., Professor of Human Anatomy in the University of Oxford. Exeter College, Oxford.
1912. §Thomson, D. C. 'Courier' Buildings, Dundee.
1909. *Thomson, E. 22 Monument-avenue, Swampscott, Mass., U.S.A.
1906. §Thomson, F. Ross, F.G.S. Hensill, Hawkhurst, Kent.
1919. *Thomson, Godfrey, H., D.Sc., Ph.D. Armstrong College, Newcastle-on-Tyne.
1914. §Thomson, Hedley J., Assoc.M.Inst.C.E. 30 Montalt-road, Woodford Green, Essex.
1890. *Thomson, Professor J. Arthur, M.A., F.R.S.E. Castleton House, Old Aberdeen.
1883. ‡Thomson, Sir J. J., O.M., M.A., Sc.D., D.Sc., Pres. R.S. (President, 1909; Pres. A, 1896; Council, 1893–95), Master of Trinity College and Professor of Experimental Physics in the University of Cambridge. Trinity College, Cambridge.
1889. *Thomson, James, M.A. 22 Wentworth-place, Newcastle-upon-Tyne.
1902. ‡Thomson, James Stuart. 4 Highfield, Chapel-en-le-Frith, Derbyshire.

Year of Election.

1871. *Thomson, John Millar, LL.D., F.R.S. (Council, 1895–1901), Professor of Chemistry in King's College, London. 55 Bedford-gardens, W. 8.
1874. §Thomson, William, F.R.S.E., F.C.S. Royal Institution, Manchester.
1906. ‡Thornely, Miss A. M. M. Oaklands, Langham-road, Bowdon, Cheshire.
1905. *Thornely, Miss L. R. Nunclose, Grassendale, Liverpool.
1898. *Thornton, W. M., O.B.E., D.Sc., Professor of Electrical Engineering in the Armstrong College, Newcastle-on-Tyne.
1902. ‡Thornycroft, Sir John I., F.R.S., M.Inst.C.E. Eyot Villa, Chiswick Mall, W. 4.
1903. ‡Thorp, Edward. 87 Southbank-road, Southport.
1881. ‡Thorp, Fielden. Blossom-street, York.
1898. ‡Thorpe, Jocelyn Field, C.B.E., Ph.D., F.R.S., Professor of Organic Chemistry in the Imperial College of Science and Technology, S.W. 7.
1871. ‡Thorpe, Sir T. E., C.B., Ph.D., LL.D., F.R.S., F.R.S.E., F.C.S. (Pres. B, 1890; Council, 1886–92.) Whinfield, Salcombe, Devon.
1899. §Threlfall, Sir Richard, K.B.E., M.A., F.R.S. Oakhurst, Church-road, Edgbaston, Birmingham.
1896. §Thrift, William Edward, M.A. (Local Sec. 1908), Professor of Natural and Experimental Philosophy in the University of Dublin. 80 Grosvenor-square, Rathmines, Dublin.
1919. §Thring, Leonard G. P. Fen Ditton Hall, Cambridge.
1919. *Tierney, Clarence, D.Sc. Netherton, Coulsdon, Surrey.
1905. ‡Tietz, Heinrich, B.A., Ph.D. South African College, Cape Town.
1874. ‡Tilden, Sir William A., D.Sc., F.R.S., F.C.S. (Pres. B, 1888; Council, 1898–1904.) The Oaks, Northwood, Middlesex.
1913. ‡Tilley, J. W. Field House, Harborne, Park-road, Birmingham.
1899. *Tims, H. W. Marett, M.A., M.D., F.L.S. Bedford College, Regent's Park, N.W. 1.
1914. ‡Tims, Mrs. Marett. Bedford College, Regent's Park, N.W. 1.
1916. ‡Tinker, Frank. The University, Birmingham.
1902. ‡Tipper, Charles J. R., B.Sc. 21 Greenside, Kendal.
1905. ‡Tippett, A. M., M.Inst.C.E. Cape Government Railways, Cape Town.
1911. *Tizard, Henry T. Oriel College, Oxford.
1900. *Tocher, J. F., D.Sc., F.I.C. Crown-mansions, 41½ Union-street, Aberdeen.
1912. ‡Todd, John A. 3 Mapperley Hall-drive, Nottingham.
1907. ‡Todd, Professor J. L. MacDonald College, Quebec, Canada.
1889. ‡Toll, John M. 49 Newsham-drive, Liverpool.
1875. ‡Torr, Charles Hawley. 35 Burlington-road, Sherwood, Nottingham.
1909. ‡Tory, H. M. Edmonton, Alberta, Canada.
1912. ‡Tosh, Elmslie. 11 Reform-street, Dundee.
1901. ‡Townsend, J. S., M.A., F.R.S., Professor of Physics in the University of Oxford. New College, Oxford.
1870. ‡Traill, William A. Giant's Causeway Electric Tramway, Portrush, Ireland.
1914. *Treckman, C. T. Hudworth Tower, Castle Eden, Durham.
1908. ‡*Treen, Rev. Henry M., B.Sc.* 3 *Stafford-road, Weston-super-Mare.*
1908. ‡Tremain, Miss Caroline P., B.A. Alexandra Hall, Aberystwyth.
1911. ‡Tremearne, Mrs., LL.A., F.L.S. 105 Blackheath-park, S.E. 3.

Year of Election.

1914. ‡Tremearne, Mrs. Ada J. Mandeville Hall, Clendon-road, Toorak, Victoria.
1887. *Trench-Gascoigne, Mrs. F. R. Lotherton Hall, Parlington, Aberford, Leeds.
1903. ‡Trenchard, Hugh. The Firs, Clay Hill, Enfield.
1908. ‡*Tresilian, R. S. Cumnor, Eglington-road, Dublin.*
1916. ‡Trevelyan, C. P., M.P. Cambo, Morpeth.
1905. ‡Trevor-Battye, A., M.A., F.L.S., F.R.G.S. Stoner Hill, Petersfield, Hants.
1916. ‡Tripp, Dr. E. H. 40 Trewsbury-road, Sydenham, S.E. 26.
1884. *Trotter, Alexander Pelham. Athenæum Club, Pall Mall, S.W. 1.
1914. ‡Trouton, Eric. The Rydings, Redington-road, Hampstead, N.W. 3.
1887. *Trouton, Frederick T., M.A., Sc.D., F.R.S. (Pres. A, 1914; Council, 1911–14.) The Rydings, Redington-road, Hampstead, N.W. 3.
1914. ‡Trouton, Mrs. The Rydings, Redington-road, Hampstead, N.W. 3.
1898. *Trow, Albert Howard, D.Sc., F.L.S., Principal of University College, Cardiff.
1913. ‡Tschugaeff, Professor L. The University, Petrograd.
1885. *Tubby, A. H., C.B., C.M.G., A.M.S., F.R.C.S. 68 Harley-street, W. 1.
1905. §Turmeau, Charles. Claremont, Victoria Park, Wavertree, Liverpool.
1912. ‡Turnbull, John. City Chambers, Dundee.
1901. §Turnbull, Robert, B.Sc. Department of Agriculture and Technical Instruction, Dublin.
1914. ‡Turner, Dr. A. J. Wickham-terrace, Brisbane, Australia.
1919. *Turner, Mrs. Agnes Margaret. 9 Blackhall-road, Oxford.
1893. ‡Turner, Dawson, M.D., F.R.S.E. 37 George-square, Edinburgh.
1913. §Turner, G. M. Abbey Hill, Kenilworth.
1894. *Turner, H. H., M.A., D.Sc., F.R.S., F.R.A.S. (General Secretary, 1913- ; Pres. A, 1911), Professor of Astronomy in the University of Oxford. University Observatory, Oxford.
1916. ‡Turner, Miss J., B.A. 14 Endsleigh-street, W.C. 1.
1919. *Turner, Miss Ruth Margaret Whyte. 9 Blackhall-road, Oxford.
1905. ‡Turner, Rev. Thomas. St. Saviour's Vicarage, 50 Fitzroy-street, W. 1.
1886. *Turner, Thomas, M.Sc., A.R.S.M., F.I.C., Professor of Metallurgy in the University of Birmingham. 75 Middleton Hall-road, King's Norton.
1910. *Turner, W. E. S. The University, Sheffield.
1890. *Turpin, G. S., M.A., D.Sc. High School, Nottingham.
1907. §Tutton, A. E. H., M.A., D.Sc., F.R.S. (Council, 1908–12.) Duart, Yelverton, South Devon.
1915. *Tweedale, Samuel. Sanbridge House, Castleton, Manchester.
1886. *Twigg, G. H. Rednall, near Birmingham.
1899. ‡Twisden, John R., M.A. 14 Gray's Inn-square, W.C. 1.
1907. §Twyman, F. 75A Camden-road, N.W. 1.
1911. *Tyndall, A. M., M.Sc. The University, Bristol.
1912. ‡Tyrrell, G. W. Geological Department, The University, Glasgow.

1884. *Underhill, G. E., M.A. Magdalen College, Oxford.
1903. ‡Underwood, Captain J. C. 60 Scarisbrick New-road, Southport.

Year of Election.

1908. §Unwin, Ernest Ewart, M.Sc. Grove House, Leighton Park School, Reading.
1883. ‡Unwin, John. Eastcliffe Lodge, Southport.
1876. *Unwin, W. C., F.R.S., M.Inst.C.E. (Pres. G, 1892; Council, 1892–99.) 7 Palace Gate-mansions, Kensington, W. 8.
1909. ‡Urquhart, C. 239 Smith-street, Winnipeg, Canada.
1880. ‡Ussher, W. A. E., F.G.S. 28 Jermyn-street, S.W. 1.
1905. ‡Uttley, E. A., Electrical Inspector to the Rhodesian Government, Bulawayo.

1887. *Valentine, Miss Anne. The Elms, Hale, near Altrincham.
1912. ‡Valentine, C. W. Queen's University, Belfast.
1908. ‡Valera, Edward de. University College, Blackrock, Dublin.
1919. §Van der Pol, Balth., jun. 95 Parklaan, Haarlem, Holland.
1865. *Varley, S. Alfred. Arrow Works, Jackson-road, Holloway, N. 7.
1917. §Varley, W. Mansergh, M.A., D.Sc., Ph.D. 7 Preston Park-avenue, Brighton
1903. ‡Varwell, H. B. Sittaford, West-avenue, Exeter.
1919. §Vasconcellos, A. de. 50 Westby-road, Boscombe, Bournemouth.
1917. §Vassall, Archer, M.A., F.Z.S. Elmfield, Harrow.
1909. *Vassall, H., M.A. The Priory, Repton, Derby.
1905. ‡Vaughan, E. L. Eton College, Windsor.
1913. ‡Vaughton, T. A. Livery-street, Birmingham.
1881. ‡Veley, V. H., M.A., D.Sc., F.R.S. 8 Marlborough-place, St. John's Wood, N.W. 8.
1883. *Verney, Lady. Plâs Rhoscolyn, Holyhead.
1904. *Vernon, H. M., M.A., M.D. 5 Park Town, Oxford.
1890. *Villamil, Lieut.-Colonel R. de, R.E. Carlisle Lodge, Rickmansworth.
1906. *Vincent, J. H., M.A., D.Sc. L.C.C. Paddington Technical Institute, Saltram-crescent, W. 9.
1899. *Vincent, Swale, M.D., D.Sc. (Local Sec. 1909), Professor of Physiology in the University of London.
1883. *Vines, Sydney Howard, M.A., D.Sc., F.R.S., F.L.S. (Pres. K, 1900; Council, 1894–97), Professor of Botany in the University of Oxford. Headington Hill, Oxford.
1902. ‡Vinycomb, T. B. Ardmore, Shooter's Hill, S.E. 18.
1904. §Volterra, Professor Vito. Regia Università, Rome.

1904. §Wace, A. J. B. Leslie Lodge, St. Albans.
1916. §Waddell, Kerr. Riverslea, Grassendale Park, Liverpool.
1909. ‡Wadge, Herbert W., M.D. 754 Logan-avenue, Winnipeg, Canada.
1888. ‡Wadworth, H. A. Breinton Court, near Hereford.
1914. ‡Wadsworth, Arthur. Commonwealth Parliament, Melbourne.
1890. §Wager, Harold W. T., D.Sc., F.R.S., F.L.S. (Pres. K, 1905.) Hendre, Horsforth-lane, Far Headingley, Leeds.
1900. ‡Wagstaff, C. J. L., B.A. Haberdashers' School, Cricklewood, N.W.
1905. §Wakefield, Captain E. W. Stricklandgate House, Kendal.
1917. *Wakefield, Miss Elsie M., F.L.S. The Herbarium, Royal Botanic Gardens, Kew.
1916. §Wale, Bernard N. Rosemont, 26 Powderham-road, Newton Abbot, Devon.
1894. ‡Walford, Edwin A., F.G.S. 21 West Bar, Banbury.

Year of Election.

1882. *Walkden, Samuel, F.R.Met.S. Windypost, Broadstairs, Kent.
1890. ‡Walker, A. Tannett. The Elms, Weetwood, Leeds.
1893. ‡Walker, Alfred O., F.L.S. Ulcombe Place, Maidstone, Kent.
1901. *Walker, Archibald, M.A., F.I.C. Newark Castle, Ayr, N.B.
1904. §Walker, E. R., J.P. 30 Park-avenue, Southport.
1911. *Walker, E. W. Ainley, M.A. University College, Oxford.
1897. *Walker, Sir Edmund, C.V.O., D.C.L., F.G.S. (Local Sec. 1897.) Canadian Bank of Commerce, Toronto, Canada.
1915. §Walker, Edward J., M.D. 46 Deansgate-arcade, Manchester.
1916. ‡Walker, F. H. 3 Stannington-grove, Heaton, Newcastle-on-Tyne.
1894. *Walker, Dr. G. T., C.S.I., M.A., F.R.S., F.R.A.S. Meteorological Office, Simla, India.
1897. ‡Walker, George Blake, M.Inst.C.E. Tankersley Grange, near Barnsley.
1913. §Walker, George W., M.A., F.R.S. Heath Cottage, Boar's Hill, near Oxford.
1906. ‡Walker, J. F. E. Gelson, B.A. 45 Bootham, York.
1894. *Walker, James, M.A. 30 Norham-gardens, Oxford.
1910. *Walker, James, D.Sc., F.R.S. (Pres. B, 1911), Professor of Chemistry in the University of Edinburgh. 5 Wester Coates-road, Edinburgh.
1906. ‡*Walker, Dr. Jamieson.* 37 *Charnwood-street, Derby.*
1915. ‡Walker, Professor Miles. School of Technology, Manchester.
1907. ‡Walker, Philip F., F.R.G.S. 36 Prince's-gardens, S.W. 7.
1909. §Walker, Mrs. R. 3 Riviera-terrace, Rushbrooke, Queenstown, Co. Cork.
1908. *Walker, Robert. Ormidale, Combe Down, Bath.
1888. ‡Walker, Sydney F. 1 Bloomfield-crescent, Bath.
1919. §Walker, W. T., B.Sc., F.G.S. Wallasey Villa, Wallasey-road, Wallasey, Cheshire.
1914. ‡Walkom, A. B. The University, Brisbane, Australia.
1910. ‡Wall, G. P., F.G.S. 32 Collegiate-crescent, Sheffield.
1883. ‡Wall, Henry. 14 Park-road, Southport.
1911. ‡Wall, Thomas F., D.Sc., Assoc.M.Inst.C.E. The University, Birmingham.
1916. ‡Wallace, Colonel Johnstone. Parkholme, Beech Grove-road, Newcastle-on-Tyne.
1920. MR Wallace, Prof. Robert, University, Edinburgh.
1905. ‡*Wallace, R. W.* 2 *Harcourt-buildings, Temple, E.C.* 4.
1901. ‡Wallace, William, M.A., M.D. 25 Newton-place, Glasgow.
1887. *Waller, Augustus D., M.D., F.R.S. (Pres. I, 1907.) 32 Grove End-road, N.W. 8.
1905. ‡Waller, Mrs. 32 Grove End-road, N.W. 8.
1913. *Waller, J. C., B.A. 32 Grove End-road, N.W. 8.
1913. *Waller, Miss M. D., B.Sc. 32 Grove End-road, N.W. 8.
1913. *Waller, W. W., B.A. 32 Grove End-road, N.W. 8.
1915. §Wallis, B. C. 18 Nassau-street, W. 1.
1895. ‡Wallis, E. White, F.S.S. Royal Sanitary Institute and Parkes Museum, 90 Buckingham Palace-road, S.W. 1.
1894. *Walmisley, A. T., M.Inst.C.E. 9 Victoria-street, Westminster, S.W. 1.
1891. §Walmsley, R. M., D.Sc. Northampton Institute, Clerkenwell, E.C. 1.
1903. ‡*Walsh, W. T. H. Kent Education Committee, Caxton House, Westminster, S.W.* 1.
1902. *Walter, Miss L. Edna. 18 Norman-road, Heaton Moor, Stockport.
1904. *Walters, William, jun. Albert House, Newmarket.
1887. ‡Ward, Sir A. W., M.A., Litt.D., Master of Peterhouse, Cambridge.

Year of Election.

1911. ‡Ward, A. W. Town Hall, Portsmouth.
1881. §Ward, George, F.C.S. Buckingham-terrace, Headingley, Leeds.
1914. ‡Ward, L. Keith, B.E. Burnside-road, Kensington Park, South Australia.
1914. §Ward, Thomas W. Endcliffe Vale House, Sheffield.
1919. §Wareing, Miss Susan. Brook War Hospital, Woolwich, S.E.18.
1905. ‡Warlow, Dr. G. P. 15 Hamilton-square, Birkenhead.
1887. ‡Warren, General Sir Charles, R.E., K.C.B., G.C.M.G., F.R.S., F.R.G.S. (Pres. E, 1887.) Athenæum Club, S.W. 1.
1913. ‡Warren, William Henry, LL.D., M.Sc., M.Inst.C.E., Challis Professor of Engineering in the University of Sydney, N.S.W.
1913. ‡Warton, Lieut.-Colonel R. G. St. Helier, Jersey.
1914. ‡Waterhouse, G. A., B.Sc. Royal Mint, Sydney, N.S.W.
1875. *Waterhouse, Major-General J. Hurstmead, Eltham, Kent.
1905. ‡Watermeyer, F. S., Government Land Surveyor. P.O. Box 973, Pretoria, South Africa.
1916. §Waters, Miss Charlotte M. Cotswold, Hurst Green, Oxted, Surrey.
1900. ‡Waterston, David, M.D., F.R.S.E. King's College, Strand, W.C. 2.
1909. §Watkinson, Professor W. H. The University, Liverpool.
1884. ‡Watson, A. G., D.C.L. Uplands, Wadhurst, Sussex.
1901. *Watson, Arnold Thomas, F.L.S. Southwold, Tapton Crescent-road, Sheffield.
1886. *Watson, C. J. Alton Cottage, Botteville-road, Acock's Green, Birmingham.
1906. ‡Watson, D. M. S., M.Sc. University College, London, W.C. 1.
1909. ‡Watson, Ernest Ansley, B.Sc. Alton Cottage, Botteville-road, Acock's Green, Birmingham.
1892. ‡Watson, G., M.Inst.C.E. 5 Ruskin-close, Hampstead Way, N.W. 4.
1885. ‡Watson, Deputy Surgeon-General G. A. Hendre, Overton Park, Cheltenham.
1915. *Watson, G. N., Sc.D., D.Sc., F.R.S., Professor of Mathematics in the University of Birmingham.
1906. *Watson, Henry Angus. 3 Museum-street, York.
1913. ‡Watson, John D., M.Inst.C.E. Tyburn, Birmingham.
1919. §Watson, Miss K., D.Sc. University College, W.C. 1.
1915. *Watson, Walter, D.Sc. Taunton School, Somerset.
1879. *Watson, William Henry, F.C.S., F.G.S. Braystones House, Beckermet, Cumberland.
1901. ‡Watt, Harry Anderson, M.P. Ardenslate House, Hunter's Quay, Argyllshire.
1913. *Watt, James. 28 Charlotte-square, Edinburgh.
1875. *Watts, John, B.A., D.Sc. Merton College, Oxford.
1873. *Watts, W. Marshall, D.Sc. Shirley, Venner-road, Sydenham, S.E. 26.
1883. *Watts, W. W., M.A., M.Sc., F.R.S., F.G.S. (Pres. C, 1903; Council, 1902-09), Professor of Geology in the Imperial College of Science and Technology, London, S.W. 7.
1896. §Wavertree, Right Hon. Lord. Gateacre, Liverpool.
1919. §Webb, G. D. 10 Bath-road, Bournemouth.
1907. ‡Webb, Wilfred Mark, F.L.S. The Hermitage, Hanwell, W. 7.
1910. ‡Webster, Professor Arthur G. Worcester, Massachusetts, U.S.A.
1919. §Webster, Miss E. Ruth. Ashbrook, Arbroath.
1919. §Webster, Sir Francis. Ashbrook, Arbroath.
1910. ‡Webster, William, M.D. 1252 Portage-avenue, Winnipeg, Canada.
1919. *Wedd, Arthur J. Eastdon House, Longport, Somerset.
1904. ‡*Wedderburn, Ernest Maclagan, D.Sc., F.R.S.E.* 7 *Dean Park-crescent, Edinburgh.*

Year of Election.

1903. ‡Weekes, R. W., A.M.Inst.C.E. 65 Hayes-road, Bromley, Kent.
1914. ‡Weir, G. North Mine, Broken Hill, New South Wales.
1890. *Weiss, Frederick Ernest, D.Sc., F.R.S. F.L.S., (Pres. K, 1911; Council, 1914–), Professor of Botany in the Victoria University, Manchester.
1905. ‡Welby, Miss F. A. Hamilton House, Hall-road, N.W. 8.
1916. ‡Welch, J. J., M.Sc., Professor of Naval Architecture in Armstrong College, Newcastle-on-Tyne.
1902. ‡Welch, R. J. 49 Lonsdale-street, Belfast.
1880. *Weldon, Mrs. Merton Lea, Oxford.
1908. ‡Welland, Rev. C. N. Wood Park, Kingstown, Co. Dublin.
1881. §Wellcome, Henry S. Snow Hill-buildings, E.C.
1911. ‡Welldon, Right Rev. J. E. C., D.D. (Pres. L, 1911.) The Deanery, Durham.
1920. MR Wells, Henry M. 11 Haymarket, S.W. 1.
1881. ‡Wells, Rev. Edward, M.A. West Dean Rectory, Salisbury.
1911. *Welsford, Miss E. J., F.L.S. Imperial College of Science and Technology, S.W. 7.
1886. *Wertheimer, Julius, D.Sc., B.A., F.I.C., Dean of the Faculty of Engineering in the University of Bristol.
1919. §West, R. Rolleston, D.S.O. 15 Wimpole-street, W. 1.
1903. ‡Westaway, F. W. 1 Pemberley-crescent, Bedford.
1882. *Westlake, Ernest, F.G.S. Fordingbridge, Salisbury.
1900. ‡Wethey, E. R., M.A., F.R.G.S. 4 Cunliffe-villas, Manningham, Bradford.
1916. ‡Weyman, G. Saltwell-road, Low Fell, Gateshead.
1916. *Wheawill, Charles. 104 Birkby Hall-road, Huddersfield.
1909. ‡Wheeler, A. O., F.R.G.S. The Alpine Club of Canada, Sidney, B.C., Canada.
1893. *Whetham, W. C. D., M.A., F.R.S. Upwater Lodge, Cambridge.
1888. ‡Whidborne, Miss Alice Maria. Charanté, Torquay.
1912. ‡Whiddington, R., M.A., D.Sc. St. John's College, Cambridge.
1913. ‡Whipp, E. M. 14 St. George's-road, St. Anne's-on-Sea.
1912. *Whipple, F. J. W., M.A. Meteorological Office, South Kensington, S.W. 7.
1898. *Whipple, Robert S. Scientific Instrument Company, Cambridge.
1859. *Whitaker, William, B.A., F.R.S., F.G.S. (Pres. C, 1895; Council, 1890-96, 1917–) 3 Campden-road, Croydon.
1884. ‡Whitcher, Arthur Henry. Dominion Lands Office, Winnipeg, Canada.
1897. ‡Whitcombe, George. The Wotton Elms, Wotton, Gloucester.
1886. ‡White, A. Silva. 42 Stevenage-road, S.W.
1908. ‡White, Mrs. A. Silva. 42 Stevenage-road, S.W.
1913. ‡*White, Mrs. E. W. Anelgate, Harborne-road, Edgbaston, Birmingham.*
1904. ‡*White, H. Lawrence, B.A. 33 Rossington-road, Sheffield.*
1885. *White, J. Martin. Balruddery, Dundee.
1914. ‡White, Dr. Jean. Prickly Pear Experimental Station, Dulacca, Queensland, Australia.
1910. *White, Mrs. Jessie, D.Sc., B.A. 49 Gordon-mansions, W.C. 13.
1912. ‡White, R. G., M.Sc., Professor of Agriculture in University College, Bangor, North Wales.
1916. §White, Colonel R. Saxton. Shirley, Jesmond, Newcastle-on-Tyne.
1877. *White, William. 20 Hillersdon-avenue, Church-road, Barnes, S.W. 13.
1916. ‡Whitehead, A. N., Sc.D., F.R.S. (Pres. A, 1916), Professor of Applied Mathematics in the Imperial College of Science and Technology, S.W. Andrews Wood, Limpsfield, Oxted, Surrey.

Year of Election.

1904. ‡WHITEHEAD, J. E. L., M.A. (Local Sec. 1904.) Guildhall, Cambridge.
1913. ‡*Whitehouse, Richard H., M.Sc. Queen's University, Belfast.*
1905. ‡Whiteley, Miss M. A., D.Sc. Imperial College of Science and Technology, S.W. 7.
1993. §Whiteley, R. Lloyd, F.C.S., F.I.C. 65 Birmingham-road, West Bromwich.
1907. *Whitley, E. 13 Linton-road, Oxford.
1905. *Whitmee, H. B. P.O. Box 470, Durban, Natal.
1897. ‡WHITTAKER, E. T., M.A., F.R.S., Professor of Mathematics in the University of Edinburgh.
1919. *Whittaker-Swinton, Captain J., R.E. Signals Experimental Establishment, Woolwich, S.E.
1919. *Whittaker-Swinton, Mrs. The Towers, Belmont, Hastings.
1919. §Whitting, C. J. 83 Poole-road, Bournemouth.
1901. ‡Whitton, James. City Chambers, Glasgow.
1913. §WICKSTEED, Rev. PHILIP H., M.A. (Pres. F, 1913.) Childrey, Wantage, Berkshire.
1916. §Widdas, Percy, B.Sc. Oakwood, Cockfield, Co. Durham.
1919. §Wigg, H. G., D.Sc. Fairlight, Wesley Park-road, Selly Oak, Birmingham.
1912. ‡Wight, Dr. J. Sherman. 30 Schermerhorn-street, Brooklyn, U.S.A.
1889. *WILBERFORCE, L. R., M.A., Professor of Physics in the University of Liverpool.
1914. ‡Wilcock, J. L. 9 East-road, Lancaster.
1910. §Wilkins, C. F. Lower Division, Eastern Jumna Canal, Delhi.
1904. ‡Wilkinson, Hon. Mrs. Dringhouses Manor, York.
1900. ‡Wilkinson, J. B. Holme-lane, Dudley Hill, Bradford.
1915. *Willans, J. B. Dolforgan, Kerry, Montgomeryshire.
1913. ‡Willcox, J. Edward, M.Inst.C.E. 27 Calthorpe-road, Edgbaston, Birmingham.
1903. ‡Willett, John E. 3 Park-road, Southport.
1916. §Willey, F. C., R.N. 28 Kyverdale-road, Stoke Newington, N. 16.
1904. **Williams, Miss Antonia. 6 Sloane-gardens, S.W. 1.*
1916. ‡Williams, Dr. Ethel. 3 Osborne-terrace, Newcastle-on-Tyne.
1905. §Williams, Gardner F., LL.D 2100 Vallejo-street, San Francisco.
1883. ‡Williams, Rev. H. Alban, M.A. Sheering Rectory, Harlow, Essex.
1861. *Williams, Harry Samuel, M.A., F.R.A.S. 6 Heathfield, Swansea.
1875. *Williams, Rev. Herbert Addams. Llangibby Rectory, near Newport, Monmouthshire.
1920. MR Williams, Professor J. Lloyd, D.Sc. University College, Aberystwyth.
1891. ‡Williams, J. A. B., M.Inst.C.E. 22 Lansdown-place, Cheltenham.
1883. *Williams, Mrs. J. Davies. 5 Chepstow-mansions, Bayswater, W. 2.
1901. *Williams, Miss Mary. 16 Campden House-road, W. 8.
1916. §Williams, Miss Maud. 15 Upper Cheyne-row, S.W. 3.
1883. ‡Williams, T. H. 27 Water-street, Liverpool.
1877. *WILLIAMS, W. CARLETON, F.C.S. Broomgrove, Goring-on-Thames.
1894. *Williamson, Mrs. Janora. 18 Rosebery-gardens, Crouch End, N. 8.
1910. ‡Williamson, K. B., Central Provinces, India. Care of Messrs. Grindlay & Co., 54 Parliament-street, S.W. 1.
1913. ‡Willink, H. G. Hillfields, Burghfield, Mortimer, Berkshire.
1895. ‡WILLINK, W. (Local Sec. 1896.) 14 Castle-street, Liverpool.
1895. ‡WILLIS, JOHN C., M.A., D.Sc., F.R.S., F.L.S. Jardin Botanico, Rio de Janeiro, Brazil.
1896. ‡WILLISON, J. S. (Local Sec. 1897.) Toronto, Canada.
1913. *Wills, L. J., M.A., F.G.S. 128 Westfield-road, Edgbaston, Birmingham.

Year of Election.

1899. §Willson, George. Lendarac, Sedlescombe-road, St. Leonards-on-Sea.
1899. §Willson, Mrs. George. Lendarac, Sedlescombe-road, St. Leonards-on-Sea.
1913. ‡Wilmore, Albert, D.Sc., F.G.S. Fernbank, Colne.
1911. *Wilmott, A. J., B.A. Natural History Museum, S.W. 7.
1911. §Wilsmore, Professor N. T. M., D.Sc. The University, Perth, Western Australia.
1911. ‡Wilsmore, Mrs. The University, Perth, Western Australia.
1901. ‡Wilson, A. Belvoir Park, Newtownbreda, Co. Down.
1878. ‡Wilson, Professor Alexander S., M.A., B.Sc. United Free Church Manse, North Queensferry.
1907. ‡Wilson, A. W. Low Slack, Queen's-road, Kendal.
1903. ‡Wilson, C. T. R., M.A., F.R.S. Sidney-Sussex College, Cambridge.
1894. *Wilson, Charles J., F.I.C., F.C.S. 14 Suffolk-street, Pall Mall, S.W. 1.
1904. §Wilson, Charles John, F.R.G.S. Deanfield, Hawick, Scotland.
1912. ‡Wilson, David, M.A., D.Sc. Carbeth, Killearn, N.B.
1904. ‡Wilson, David, M.D. Glenfield, Deighton, Huddersfield.
1912. *Wilson, David Alec. 1 Broomfield-road, Ayr.
1900. *Wilson, Duncan R. 44 Whitehall-court, S.W. 1.
1895. ‡Wilson, Dr. Gregg. Queen's University, Belfast.
1914. ‡Wilson, H. C. Department of Agriculture, Research Station, Werribee, Victoria.
1901. ‡Wilson, Harold A., M.A., D.Sc., F.R.S., Professor of Physics in the Rice Institute, Houston, Texas.
1902. *Wilson, Harry, F.I.C. 30 Westwood-road, Southampton.
1879. ‡Wilson, Henry J. Osgathorpe Hills, Sheffield.
1910. *Wilson, J. S. Widnerpoole, Grove-road, Sutton, Surrey.
1913. ‡Wilson, Professor J. T., M.B., F.R.S. University of Sydney, Sydney, N.S.W.
1908. ‡Wilson, Professor James, M.A., B.Sc. 40 St. Kevin's-park, Dartry-road, Dublin.
1879. ‡Wilson, John Wycliffe. Easthill, East Bank-road, Sheffield.
1901. *Wilson, Joseph, F.R.M.S. The Hawthorns, 3 West Park-road, Kew Gardens, Surrey.
1908. *Wilson, Malcolm, D.Sc., F.L.S., Lecturer in Mycology and Bacteriology in the University of Edinburgh. Royal Botanic Gardens, Edinburgh.
1908. §Wilson, Miss Mary. Glenfield, Deighton, Huddersfield.
1909. §Wilson, R. A. Hinton, Londonderry.
1892. ‡*Wilson, T. Stacey, M.D.* 27 *Wheeley's-road, Edgbaston, Birmingham.*
1887. §Wilson, W. Battlehillock, Kildrummy, Mossat, Aberdeenshire.
1909. ‡Wilson, W. Murray. 29 South-drive, Harrogate.
1919. §Wilson, William, M.B. 43 Fellows-road, N.W. 3.
1910. ‡Wilton, T. R., M.A., Assoc.M.Inst.C.E. 18 Westminster-chambers, Crosshall-street, Liverpool.
1907. §Wimperis, H. E., M.A. Grahamsfield, Goring-on-Thames.
1910. ‡Winder, B. W. Ceylon House, Sheffield.
1886. ‡Windle, Sir Bertram C. A., M.A., M.D., D.Sc., F.R.S., President of University College, Cork.
1863. *Winwood, Rev. H. H., M.A., F.G.S. (Local Sec. 1864.) 11 Cavendish-crescent, Bath.
1905. §Wiseman, J. G., F.R.C.S., F.R.G.S. Stranraer, St. Peter's-road, St. Margaret's-on-Thames.
1919. §Withers, Hartley. 'The Economist,' 3 Arundel-street, W.C. 2.
1914. ‡Witkiewicz, S. Care of Dr. Malinowski, London School of Economics, Clare Market, W.C. 2.

Year of Election.

1913. ‡Wohlgemuth, Dr. A. 44 Church-crescent, Muswell Hill, N. 10.
1915. ‡Wolff, C. E. The Clough, Hale, Cheshire.
1905. ‡Wood, A., jun. Emmanuel College, Cambridge.
1863. *Wood, Collingwood L. Freeland, Forgandenny, N.B.
1875. *Wood, George William Rayner. Singleton Lodge, Manchester.
1878. ‡Wood, Sir H. Trueman, M.A. Prince Edward's-mansions, Bayswater, W.
1908. ‡Wood, Sir Henry J. 4 Elsworthy-road, N.W. 3.
1912. ‡Wood, John K. 304 Blackness-road, Dundee.
1914. ‡Wood, Mrs. M. J. Springfield, Sidgwick-avenue, Cambridge.
1904. *Wood, T. B., C.B.E., M.A., F.R.S. (Pres. M., 1913; Council, 1915–16), Professor of Agriculture in the University of Cambridge. Caius College, Cambridge.
1899. *Wood, W. Hoffman. Queen-square House, Leeds.
1901. *Wood, William James, J.P., F.S.A.(Scot.). 266 George-street, Glasgow.
1896. *Woodhead, Professor G. Sims, M.D. Pathological Laboratory, Cambridge.
1911. §Woodhead, T. W., Ph.D., F.L.S. Technical College, Huddersfield.
1912. **Wood-Jones, F., D.Sc., Professor of Anatomy in the University of London. New Selma, Epsom, Surrey.*
1906. *Woodland, Dr. W. N. F. Zoological Department, The Muir Central College, Allahabad, United Provinces, India.
1916. ‡Woodrow, John. Berryknowe, Meikleriggs, Paisley.
1904. ‡Woods, Henry, M.A., F.R.S. Sedgwick Museum, Cambridge.
1916. ‡Woods, Henry Charles. 171 Victoria-street, S.W. 1
1887. *Woodward, Arthur Smith, LL.D., F.R.S., F.L.S., F.G.S. (Pres. C, 1909; Council, 1903–10, 1915–), Keeper of the Department of Geology, British Museum (Natural History), Cromwell-road, S.W. 7.
1869. *Woodward, C. J., B.Sc., F.G.S. The Lindens, St. Mary's-road, Harborne, Birmingham.
1912. ‡Woodward, Mrs. C. J. The Lindens, St. Mary's-road, Harborne, Birmingham.
1866. ‡Woodward, Henry, LL.D., F.R.S., F.G.S. (Pres. C, 1887; Council 1887–94.) Tudor Cottage, Clay Hill, Bushey, Herts.
1894. *Woodward, John Harold. 8 Queen Anne's-gate, Westminster, S.W. 1.
1909. *Woodward, Robert S. Carnegie Institution, Washington, U.S.A.
1908. §Woolacott, David, D.Sc., F.G.S. 8 The Oaks West, Sunderland.
1890. *Woollcombe, Robert Lloyd, M.A., LL.D., F.I.Inst., F.R.C.Inst., F.R.G.S., F.R.E.S., F.S.S., M.R.I.A. 14 Waterloo-road, Dublin.
1883. *Woolley, George Stephen. Victoria Bridge, Manchester.
1915. *Woolley, Hermann. Fairhill, Kersal, Manchester.
1914. ‡Woolnough, Professor W. S., D.Sc. University of Western Australia, Perth, Western Australia.
1912. *Wordie, James M., B.A. St. John's College, Cambridge.
1908. *Worthington, James H., M.A., F.R.A.S., F.R.G.S. The Observatory, Four-Marks, Alton.
1906. ‡Wragge, R. H. Vernon. York.
1910. ‡Wrench, E. G. Park Lodge, Baslow, Derbyshire.
1906. ‡Wright, Sir Almroth E., M.D., D.Sc., F.R.S., Professor of Experimental Pathology in the University of London. 6 Park-crescent, W. 1.
1914. ‡Wright, A. M. Islington, Christchurch, New Zealand.

Year of Election.

1883. *Wright, Rev. Arthur, D.D. Queens' College, Cambridge.
1909. ‡*Wright, C. S., B.A. Caius College, Cambridge.*
1914. ‡Wright, Gilbert. Agricultural Department, The University, Sydney, N.S.W.
1874. ‡Wright, Joseph, F.G.S. 4 Alfred-street, Belfast.
1884. ‡WRIGHT, Professor R. RAMSAY, M.A., B.Sc. Red Gables, Headington Hill, Oxford.
1911. ‡Wright, W. B., B.A., F.G.S. 14 Hume-street, Dublin.
1903. ‡Wright, William. Villa Camdens, Vicarage Way, Gerrard's Cross.
1871. ‡WRIGHTSON, Sir THOMAS, Bart., M.Inst.C.E., F.G.S. Neasham Hall, Darlington.
1902. ‡Wyatt, G. H. 1 Maurice-road, St. Andrew's Park, Bristol.
1901. ‡Wylie, Alexander. Kirkfield, Johnstone, N.B.
1902. ‡Wylie, John. 2 Mafeking-villas, Whitehead, Belfast.
1911. ‡Wyllie, W. L., R.A. Tower House, Tower-street, Portsmouth.
1899. ‡WYNNE, W. P., D.Sc., F.R.S. (Pres. B, 1913), Professor of Chemistry in the University of Sheffield. 17 Taptonville-road, Sheffield.

1901. *YAPP, R. H., M.A., Professor of Botany in the Queen's University, Belfast.
1894. *Yarrow, Sir A. F., Bart. Homestead, Hindhead, Surrey.
1913. *Yates, H. James, F.C.S., M.I.Mech.E. Redcroft, Four Oaks, Warwickshire.
1905. ‡Yerbury, Colonel. Army and Navy Club, Pall Mall, S.W. 1.
1917. §Yorke, Mrs. R. F., F.R.G.S. Ladies' Imperial Club, 17 Dover-street, Piccadilly, W. 1.
1909. §Young, Professor A. H. Trinity College, Toronto, Canada.
1904. §Young, Alfred. Selwyn College, Cambridge.
1891. ‡YOUNG, ALFRED C., F.C.S. 17 Vicar's-hill, Lewisham, S.E. 13.
1905. ‡Young, Professor Andrew, M.A., B.Sc. South African College, Cape Town.
1909. ‡Young, F. A. 615 Notre Dame-avenue, Winnipeg, Canada.
1894. *YOUNG, GEORGE, Ph.D. 46 Church-crescent, Church End, Finchley, N. 10.
1909. §Young, Herbert, M.A., B.C.L., F.R.G.S. 27 Montpelier-road, Ealing, W. 5.
1885. ‡YOUNG, R. BRUCE, M.A., M.B. 8 Crown-gardens, Dowanhill, Glasgow.
1909. ‡Young, R. G. University of North Dakota, North Chautauqua, North Dakota, U.S.A.
1901. ‡Young, Robert M., B.A. Rathvarna, Belfast.
1883. *YOUNG, SYDNEY, D.Sc., F.R.S. (Pres. B, 1904), Professor of Chemistry in the University of Dublin. 13 Clyde-road, Dublin.
1887. ‡Young, Sydney. 29 Mark-lane, E.C. 3.
1911. ‡Young, T. J. College of Agriculture, Holmes Chapel, Cheshire.
1907. *YOUNG, WILLIAM HENRY, M.A., Sc.D., Hon. Dr. ès Sc. Math., F.R.S., Professor of the Philosophy and History of Mathematics in the University of Liverpool. Redlinde, Lausanne, Switzerland.
1903. ‡Yoxall, Sir J. H. 67 Russell-square, W.C. 1.

CORRESPONDING MEMBERS.

Year of Election.

1892. Professor Svante Arrhenius. The University, Stockholm. (Bergsgatan 18.)
1913. Professor C. Barrois. Université, Lille, France.
1897. Professor Carl Barus. Brown University, Providence, R.I., U.S.A.
*1887. Hofrath Professor A. Bernthsen, Ph.D. Anilenfabrik, Ludwigshafen, Germany.
*1890. Professor Dr. L. Brentano. Friedrichstrasse 11, Munich.
1893. Professor Dr. W. C. Brögger. Universitets Mineralogske Institute, Christiania, Norway.
1894. Professor D. H. Campbell. Stanford University, Palo Alto, California, U.S.A.
1897. M. C. de Candolle. 3 Cour de St. Pierre, Geneva, Switzerland.
1887. Professor G. Capellini. 65 Via Zamboni, Bologna, Italy.
1894. Emile Cartailhac. 5 rue de la Chaine, Toulouse, France
1901. Professor T. C. Chamberlin. Chicago, U.S.A.
1913. Professor R. Chodat. Université, Geneva.
1887. F. W. Clarke. Care of the Smithsonian Institution, Washington, D.C., U.S.A.
*1913. Professor H. Conwentz. Elssholzstrasse 13, Berlin W. 57.
1889. W. H. Dall, Sc.D. United States Geological Survey, Washington, D.C., U.S.A.
1872. Dr. Yves Delage. Faculté des Sciences, La Sorbonne, Paris.
1901. Professor G. Dewalque. 17 rue de la Paix, Liége, Belgium.
*1913. Professor Carl Diener. Universität, Vienna.
1876. Professor Alberto Eccher. Florence.
1894. Professor Dr. W. Einthoven. Leiden, Netherlands.
1892. Professor F. Elfving. Helsingfors, Finland.
*1901. Professor J. Elster. Wolfenbüttel, Germany.
*1913. Professor A. Engler. Universität, Berlin.
1913. Professor Giulio Fano. Istituto di Fisiologia, Florence.
1901. Professor W. G. Farlow. Harvard, U.S.A.
*1874. Dr. W. Feddersen. Carolinenstrasse 9, Leipzig.
1913. Professor Chas. Féry. École Municipale de Physique et de Chimie Industrielles, 42 rue Lhomond, Paris.
*1886. Dr. Otto Finsch. Altewiekring, No.19b, Braunschweig, Germany.
*1894. Professor Wilhelm Foerster, D.C.L. Encke Platz 3A, Berlin, S.W.48.
1901. Professor A. P. N. Franchimont. Leiden, Netherlands.
1894. Professor Léon Fredericq. 20 rue de Pitteurs, Liége, Belgium.
*1913. Professor M. von Frey. Universität, Würzburg.
*1892. Professor Dr. Gustav Fritsch. Berlinerstrasse 30, Berlin.
1881. Professor C. M. Gariel. 6 rue Edouard Détaille, Paris.
*1901. Professor Dr. H. Geitel. Wolfenbüttel. Germany.
1889. Professor Gustave Gilson. L'Université, Louvain, Belgium.
1913. Professor E. Gley. 14 rue Monsieur le Prince, Paris.

* Membership temporarily suspended.

Year of Election.

1889. A. Gobert. 222 Chaussée de Charleroi, Brussels.
1884. General A. W. Greely, LL.D. Center Conway, N.H., U.S.A.
*1913. Professor P. H. von Groth. Universität, Munich.
1892. Dr. C. E. Guillaume. Bureau International des Poids et Mesures, Pavillon de Breteuil, Sèvres.
1916. George Ellery Hale. Astrophysical Observatory, Mount Wilson, California, U.S.A.
1881. Dr. Edwin H. Hall. 30 Langdon-street, Cambridge, Mass., U.S.A.
1913. Professor A. Haller. 10 rue Vauquelin, Paris.
1913. Professor H. J. Hamburger. Physiological Institute, Groningen.
1893. Professor Paul Heger. 23 rue de Drapiers, Brussels.
*1894. Professor Ludimar Hermann. Universität, Königsberg, Prussia.
*1893. Professor Richard Hertwig. Zoologisches Institut, Alte Akademie, Munich.
1913. Professor A. F. Holleman. Universiteit, Amsterdam.
1887. Dr. Oliver W. Huntington. Cloyne House, Newport, R.I., U.S.A.
1884. Professor C. Loring Jackson. 383 Bearon-street, Boston, Massachusetts, U.S.A.
1876. Dr. W. J. Janssen. Chernex s. Montreux, Switzerland.
1881. W. Woolsey Johnson, Professor of Mathematics in the United States Naval Academy, Annapolis, Maryland, U.S.A.
1887. Professor C. Julin. 159 rue de Fragnée, Liége.
1876. Dr. Giuseppe Jung. Viale Bianca 21, Milan.
1913. Professor J. C. Kapteyn. Universiteit, Gröningen.
1913. Professor A. E. Kennelly. Harvard University, Cambridge, Massachusetts, U.S.A.
*1873. Professor Dr. Felix Klein. Wilhelm-Weberstrasse 3, Göttingen.
*1894. Professor Dr. L. Kny. Kaiser-Allee 186–7, Wilmersdorf, bei Berlin.
1913. Professor D. J. Korteweg. Universiteit, Amsterdam.
*1913. Professor A. Kossel. Physiologisches Institut, Heidelberg.
1894. *Maxime Kovalevsky.* 15 *Avenue de l'Observatoire, Paris, France.*
1913. Ch. Lallemand, Directeur-Général des Mines. 58 Boulevard Emile-Augier, Paris.
1872. M. Georges Lemoine. 76 rue Notre Dame des Champs, Paris.
*1901. Professor Philipp Lenard. Schlossstrasse 7, Heidelberg.
1920. Professor H. A. Lorentz, Zijlweg 76, Haarlem.
1887. Professor Dr. Georg Lunge. Rämistrasse 56, Zurich, V
*1913. Professor F. von Luschan. Universität, Berlin.
1913. Professor E. Mahaim. Université de Liége, Belgium.
*1887. Dr. C. A. von Martius. Voss-strasse 8, Berlin, W.
1884. Professor Albert A. Michelson. The University, Chicago, U.S.A.
1894. Professor G. Mittag-Leffler. Djursholm, Stockholm.
1897. Professor Oskar Montelius. St. Paulsgatan 11, Stockholm, Sweden.
1913. Professor E. H. Moore. University of Chicago, U.S.A.
1897. Professor E. W. Morley, LL.D. West Hartford, Connecticut, U.S.A.
1887. E. S. Morse. Peabody Academy of Science, Salem, Mass., U.S.A.
1913. Professor F. R. Moulton. University of Chicago, U.S.A.
1889. Dr. F. Nansen. Lysaker, Norway.
1894. Professor R. Nasini. Istituto Chimico, Via S. Maria, Pisa, Italy
1913. Professor E. Naville. Université, Geneva.
*1887. Professor Emilio Noelting. Mulhouse, Alsace.
1894. Professor H. F. Osborn. Columbia College, New York, U.S.A.
*1890. Professor W. Ostwald. Linnéstrasse 2, Leipzig.
1890. Maffeo Pantaleoni. 13 Cola di Rienzo, Rome.
*1895. Professor F. Paschen. Universität, Tübingen.

* Membership temporarily suspended.

Year of Election.

*1887. Dr. Pauli. Feldbergstrasse 49, Frankfurt a/Main, Germany.
*1901. Hofrath Professor A. Penck. Georgenstrasse 34–36, Berlin, N.W.7.
1890. Professor Otto Pettersson. Stockholms Hogskola, Stockholm.
*1894. Professor W. Pfeffer, D.C.L. Linnéstrasse 11, Leipzig.
*1887. Professor Georg Quincke. Bergstrasse 41, Heidelberg.
*1868. L. Radlkofer, Professor of Botany in the University of Munich. Sonnenstrasse 7.
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